VOL. XIV, NO. 6 JUNE, 1922

THE SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

CONTENTS

THE SCIENCE PRESS

PUBLICATION OFFICE: 11 LIBERTY ST., UTICA, N. Y.

EDITORIAL AND BUSINESS OFFICE: GARRISON, N. Y.

New York Office: The Grand Central Terminal

Single Number, 50 Cents. Yearly Subscription, $5.00

Entered as second-class matter November 9, 1921, at the Post Office at Utica, N. Y., under the Act of March 3, 1879.

THE SCIENTIFIC MONTHLY

JUNE, 1922

SOCIAL LIFE AMONG THE INSECTS[1]

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LECTURE I

GENERAL REMARKS ON INSECT SOCIETIES. THE SOCIAL BEETLES

DURING the past fifty years, the science of living organisms has itself, like a living organism, developed so rapidly that it has more than once changed its aspect and induced its votaries to change their points of view. The future historian of the science will probably emphasize the difference of attitude towards the living world exhibited by Darwin and his contemporaries and that of the present generation of twentieth century biologists. He will notice that the works of the Victorians abound in such phrases as the "struggle for existence," "survival of the fittest," "Nature, red in tooth and claw," and disquisitions on the unrelenting competition in the development, growth and behavior of all animals and plants. This struggle, as you know, was supposed to constitute the very basis for the survival of favored forms through natural selection. There can be no doubt that even to-day we must admit that there is much truth in all this writing, but we would insist that it depicts not more than half of the whole truth. To us it is clear that an equally pervasive and fundamental innate peculiarity of organisms is their tendency to cooperation, or "mutual aid," as it was called by Prince Kropotkin. Even to the great Victorian naturalists the fact was familiar—though they failed to dwell on its great social significance—that all living things are genetically related as members of one great family, one vast, living symplasm, which, though fragmented into individuals in space, is nevertheless absolutely continuous in time, that in the great majority of organic forms each generation arises from the cooperation of two individuals, that most animals and plants live in associations, herds, col-

[1] Lowell Lectures.

onies or societies of the same species and that even the so-called "solitary" species are obligatory, more or less cooperative members of groups or associations of individuals of different species, the biocœnoses. Living beings not only struggle and compete with one another for food, mates and safety, but they also work together to insure to one another these same indispensable conditions for development and survival. The phenomena of mutualism and coöperation are, indeed, so prevalent among plants and animals and affect their structure and behavior so profoundly that there has arisen within very recent years a new school of biologists, who might be called "symbiotists," because they devote themselves to the investigation of a whole world of microorganisms which live in the most intimate symbiosis within the very cells of many if not most of the higher animals and plants.

If asked why it seems advisable to devote six lectures to social life among the insects, I might say that these creatures exhibit many of the most extraordinary manifestations of that general organic cooperativeness which I have just mentioned, and that these manifestations have not only an academic but also a practical interest at the present time. For if there is a world-wide impulse that more than any other is animating and shaping all our individual lives since the world war, it is that towards ever greater solidarity, of general disarmament, of a drawing together not only of men to men but of nations to nations throughout the world, of a recasting and refinement of all our economic, political, social, educational and religious activities for the purposes of greater mutual helpfulness. As Edward Carpenter says:

> The sense of organic unity, of the common welfare, the instinct of Humanity, or of general helpfulness, are things which run in all directions through the very fibre of our individual and social life—just as they do through that of gregarious animals. In a thousand ways: through heredity and the fact that common ancestral blood flows in our veins—though we be only strangers that pass in the street; through psychology, and the similarity of structure and concatenation in our minds; through social linkage, and the necessity of each and all to the other's economic welfare; through personal affection and the ties of the heart; and through the mystic and religious sense which, diving deep below personalities, perceives the vast flood of universal being—in these and many other ways does this Common Life compel us to recognize itself as a fact—perhaps the most fundamental fact of existence.

The social insects may also be singled out for special treatment for the following more particular reasons: first, because they represent Nature's most startling efforts in communal organization and have therefore been held up to us since the days of Solomon as eminently worth imitating, or to be avoided as an "abschreckendes Beispiel"; second, because these organizations are simpler and more perspicuous than our own and we can study their origin,

development and decay and subject them to experimentation; third, because many of them represent clean-cut products of comparatively simple evolutionary tendencies and hence final and relatively stable accomplishments; fourth, because they show us the extent to which social organization can be developed and integrated on a purely physiological and instinctive basis, and by contrast therefore throw into sharper relief some of the defects and virtues of our own more intellectual type of society; and fifth, because they are so remote from us that we should be able to study them in an unbiased and truly scientific spirit.

I wish to dwell somewhat on the third of these reasons for the purpose of placing in clearer perspective the great antiquity and completeness of the social organization of insects. Some years ago the museums of Königsberg and Berlin sent me for study an extraordinary collection of ants in lumps of Baltic amber. There were 9,560 specimens, representing 92 species and 43 genera. As you know, the Baltic amber is merely the fossil resin of pines which flourished during Lower Oligocene Tertiary times in the region which is now Sweden. The liquid resin exuded from the tree- trunks precisely as it does to-day, and great numbers of small insects, especially ants, were trapped in the transparent, viscid masses which hardened, fell from the trees or remained after the rotting of the wood and were carried down by the streams and embedded in what is to-day the floor of the Baltic Sea and the soil of Eastern Prussia. The lumps are now brought to the surface either by mining or by the action of the waves which cast them up on the beaches. So beautiful and lifelike are the insects preserved in the amber that by comparison all other fossils have a singularly dull and inert appearance. Many of the specimens which I was able to examine were as exquisitely preserved as living ants embedded in Canada balsam by some expert microscopist. My study showed conclusively that the ants have undergone no important structural modifications since the Lower Oligocene, that they had at that time developed all their various castes just as we see them to-day, that their larvæ and pupæ were the same, that they attended plant-lice, kept guest-beetles in their nests and had parasitic mites attached to their legs in the very same peculiar positions as in our living species, and that at least six of the seven existing subfamilies and many of the existing genera were fully established. Some of the species in the amber were even found to be practically indistinguishable from those now living in Northern Europe and North America. The Baltic amber also contains social bees, wasps and termites, and though these are not so well known, what I have said of the ants will also *mutatis mutandis* prove to be true of them. Since my work was published Cockerell and

Donisthorpe have described a number of ants from the Bagshot Beds of the Isle of Wight, also of Oligocene age, and very recently Cockerell has described a typical ant, *Eoformica eocenica*, from even earlier strata, the Green River Eocene of Wyoming. We must conclude, therefore, that these insects—and the same is very probably true also of the wasps, bees and termites—had their origin in the Cretaceous, if not earlier. What I wish to emphasize is the fact that all the main structural and social peculiarities of these insects were completed by the beginning of the Tertiary and that they have since been merely marking time or developing only the slight modifications which serve to distinguish genera, species, subspecies and varieties.

Now how many years have elapsed since the beginning of the Tertiary? Geologists have, of course, made many and diverse estimates. I shall take the most recent, which are much in excess of earlier computations. Barrell gives the time since the beginning of the Tertiary as 55 to 65 million years. But the social insects are the most recent—the mere newly rich, so to speak—in the great class Insecta, which has a fossil record extending back to the Upper Carboniferous. And as our earliest known fossils are perfectly typical insects, it is probable that the earliest Hexapods made their appearance in the Silurian, if not earlier. This would make the period during which these wonderful creatures have been living and multiplying on our planet about 300 million years!

In order that we and the impatient reformers in our midst may experience the proper feeling of humility let us now compare the age of man and his society with that of the ants. During the Oligocene and early Miocene, while these insects, together with the uncouth primitive mammals, represented the dominant animal life of the plains and forests of the globe, the early Primates were just splitting into two tribes, one of which was destined to produce the modern apes, the other the Hominidæ, or humans. Our ancestors were probably just forsaking that life among the tree-tops which, as Woods Jones has shown, has left its ineffaceable impress on all the details of our anatomy. A large part of the diet of these early Hominids and their immediate ancestors probably consisted of those same ants which had already developed a cooperative communism so complete that in comparison the most radical of our bolsheviks are ultra-conservative capitalists. By a hundred thousand years ago our ancestors had reached the stage of the Neanderthal man, whose society was probably somewhat more primitive than that of the Australian savage of to-day. And so far as the actual, fundamental, biological structure of our society is concerned and notwithstanding its stupendous growth in size and all the tinkering to which it has been subjected, we are still in much

the same infantile stage. But if the ants are not despondent because they have failed to produce a new social invention or convention in 65 million years, why should we be discouraged because some of our institutions and castes have not been able to evolve a new idea in the past fifty centuries?

I find that social habits have arisen no less than 24 different times in as many different groups of solitary insects. Careful investigation of the life-histories of tropical species will probably increase this number. These 24 societies, which I propose to consider in more or less detail in this and the following lectures, represent very different stages in the evolution of the social habit. Some of them are small and depauperate, mere rudiments of societies, some are extremely populous and present great differentiation and specialization of their members, whereas others show intermediate conditions. And while each of the 24 different societies has its own peculiar features, we nevertheless observe that all of them have arisen in the same manner and have the same fundamental structure. Each is a family consisting of two parent insects and their offspring or at least of the fecundated mother and her offspring, and the members of the two generations live together in more or less intimate, cooperative affiliation. During the long history of the Insecta this situation has developed time and time again and quite naturally out of the very general propensity of female insects to lay their eggs on food suitable to the hatching larvæ or to make protective structures or burrows, to store them with food and to oviposit on it. As a rule, the mother insect then dies and never sees her offspring, but all such parental care, which is also very prevalent among many other animals and even among plants, is nevertheless a potential or implicit nursing or fostering, which readily become actual or explicit in such species as manage to survive the hatching of their young and can therefore continue to feed and protect them. It is difficult, nevertheless, to draw a hard and fast line between certain solitary forms and some of the societies or families I have selected, for there is a finely graded series of cases of parental care between complete indifference to the offspring and the families of what may be called the incipiently social or subsocial forms. As the societies grow in size and complexity they naturally change from associations in which the progeny depend on their parents to associations in which the parents come to depend on their progeny.

John Fiske and others have claimed that human society has been rendered possible by a lengthening of infancy and childhood, since this obviously involves more elaborate care of the young by the parents and a greatly increased opportunity of learning on the part of the child. This is true, but it is equally true that the adult

life of the parents must also be prolonged to cover the retarded juvenile development, and the insects show us that the lengthening of the adult stage comes first and makes social life possible. In solitary insects, of course, it is just the brevity of adult life that prevents the development of the social habit, no matter how long the larval period may be. This period may, in fact, extend over months or even years in certain insects which have an adult stage of only a few days or hours.

Momentous consequences necessarily follow from the lengthening of the adult life of the parent insect and the development of the family, for the relations between parents and offspring tend to become so increasingly intimate and interdependent that we are confronted with a new organic unit, or biological entity—a superorganism, in fact, in which through physiological division of labor the component individuals specialize in diverse ways and become necessary to one another's welfare or very existence. Since this integration necessarily leads to an important modification of the activities of the originally solitary insects composing the society it will be advisable to dwell for a few moments on the basic behavior of insects.

The activities of insects, like those of other animals, are an expression of three fundamental appetites or appetencies. Two of these—hunger and sex—are positive and possessive, the other—fear or avoidance—is negative and avertive. These appetites appear as the needs for food, progeny and protection. So far as I am able to see, they manifest themselves in insects in essentially the same manner as in the higher animals, such as birds, mammals and man. The appetites of hunger and sex arise from internal stimuli which compel the organism to make random or trial and error movements till appropriate, specific external stimuli are encountered. Then a sudden, consummatory reaction occurs and the relieved organism lapses into quiescence till the internal stimuli again make themselves felt. In the case of fear or aversion, harmful or disagreeable stimuli, usually of external origin, cause random movements till the organism escapes or succeeds in ridding itself of the noxious or discomfort-producing situation, when it becomes quiescent. And the behavior of insects, like that of other animals, seems to be made up of successions of such appetitive or avertive cycles, which may be repeated during the life-cycle, or—and this is particularly true of insects—the whole life-cycle may consist of a few appetitive cycles of very elaborate patterns—the so-called "instincts."

Now when insects or other animals, for that matter, take to living in societies these fundamental appetites, which as solitary individuals they have been exercising for millions of years, are

by no means lost or suppressed but become peculiarly modified. Since the environment of the social is from the outset much more complex than that of the solitary insect, it must respond not only to all the stimuli to which it reacted in its presocial stage but also to a great number of additional stimuli emanating from the other members of the society in which it is living. Even man, as Berman says, "with the growth of his imagination and the increase in number and density of his surrounding herd, has become the subject of continuous stimulation." The result seems to be a greatly increased responsiveness of the organism. It becomes, so to speak, socially sensitized, and all its appetites and emotions become hypertrophied or even perverted. This will be clear for the insects from the following very summary considerations:

(1.) Social life encounters serious and urgent difficulties in the matter of food, for the colony must have access to a supply which is abundant, nutritious and easily and continuously available in order that all the adult members as well as the young may be adequately nourished. Such an ideal food-supply is rare so that social insects are, as a rule, chronically hungry and in the presence of food positively greedy. Whenever possible both bees and ants gorge themselves to the utmost. While an ant is feeding on nectar or syrup her abdomen may be snipped off with a pair of scissors, without interrupting her repast. We shall see, however, that she appropriates only a very small portion of the swallowed food and that she distributes most of it among her nestmates. Hence, though she behaves like a glutton, we must refrain from regarding her as such. When we see a man importuning everybody for food or money we naturally regard him as avaricious or greedy, but when we learn that he is turning in all his collections to the Red Cross, he is transformed in our estimation. Not only does the social insect thus develop an unusual appetite for food but it also develops elaborate methods of apportioning the food among the adults and brood of the colony according to their various needs. Furthermore, the greatest economy in the use of food, which is of course energy, must be practiced and various methods of preserving and storing it for consumption during seasons of scarcity must be devised. And since insect societies must compete with many other hungry animals they tend to specialize in their diet and to take to foods that can not be readily utilized by other organisms. All this specialization leads eventually to the development of a caste peculiarly adapted to provisioning the colony. As we shall see, this caste comprises the so-called "workers."

(2.) The reproductive gives rise to even more serious difficulties than the nutritive appetite. If all the individuals in the colony are permitted to reproduce without restraint, the popula-

tion will very soon outrun the food-supply and all its members will suffer from malnutrition or starvation, or it will have to resolve itself into smaller and feebler communities, and spread over a larger territory. The higher social insects have overcome this difficulty by rigidly restricting reproduction, except when food happens to be unusually abundant, to a few individuals and suppressing it in all the others. Hence the fecundity of certain females, the queens, and of the males, or drones, becomes greatly enhanced or hypertrophied, while the remaining females, the workers, are reduced to physiological sterility. But it was found most convenient, while thus developing the queens and males as a reproductive and the workers as a nutritive caste, and depriving the latter under normal conditions of the capacity for reproduction, to leave them in possession of their primitive parental instincts, that is, an ardent propensity for nursing the brood.

(3.) In the higher social insects fear is very readily aroused and can be easily studied in all its manifestations from abject cowardice and "death-feigning" in small and feeble species to panic rage in very populous communities. It is certainly of great biological significance, because these insects and their helpless brood are sedentary, or fixed to a particular environment and are therefore exposed to the unforeseen attacks of enemies, inundations of great changes of temperature. Hence, we find that they not only make elaborate nests and fortifications but have developed powerful jaws, hard skulls, pungent or nauseating secretions and deadly stings. The workers originally assumed the protective rôle in addition to their other functions, but in many ants and most termites a special warrior or soldier caste has been evolved. Then, precisely as in man, many wasps, bees and ants found that the best method of defence is offence and their enemies were attacked before they could reach the nest. From this it was, of course, only a step to the organization of marauding and plundering expeditions and the development of aggressive warfare.

All the very complicated manifestations of the hunger, sex and fear appetites are so inextricably interwoven and interdependent that it is impossible adequately to study any one of them in isolation. I shall therefore have to refer to all of them again and again, but I wish to put the main emphasis in these lectures on the hunger appetite, because it is the most fundamental, exhibits the most astonishing developments and is found to have an even greater influence on the reproductive and protective appetites than we had supposed. The recent work of the biochemists and physiologists on the vitamines and internal or endocrine secretions, or "encretions" as some German investigators call them, has shown that extremely minute quantities of certain substances may have very

profound and far-reaching effects on the metabolism, structure and functioning of living animals, and there has long been a suspicion that the differentiation of the fertile and sterile castes among social insects may be due to very delicate chemical stimuli. I shall endeavor to show that such stimuli may also play a determining rôle in maintaining the integrity or solidarity of many insect societies.

Before describing the various societies in greater detail I wish briefly to compare them with human society. I use this word in the singular, because at the present time, owing to the greatly increased facilities of transportation and intercommunication, what were once numerous independent human societies have practically fused or are about to fuse to form one immense, world-wide society. Human and insect societies are so similar that it is difficult to detect really fundamental biological differences between them. This assertion may be supported by the following considerations:

(1.) It is sometimes said or implied that human society is a rational association, due to intelligent cooperation, or contract among its members, whereas insect societies are merely physiological or instinctive associations. The second part of this statement is correct, but he who would seek support for the first part in the works of present day sociologists, psychologists and philosophers will be disappointed. The whole trend of modern thought is towards a greater recognition of the very important and determining rôle of the irrational and the instinctive, not only in our social but also in our individual lives. The best proof of this statement is to be found in the family which by common consent constitutes the primitive basis of our society, just as it does among the insects, and the bonds which unite the human family are and will always be physiological and instinctive.

(2.) It may be said that insect societies are discrete entities, each of which arises as a single family, increases in population for some time and then dies away, whereas human society—the Great Society of Graham Wallas—is a mixtures of families and groups which grow and continue indefinitely. This is an important distinction but not absolute, since human society must have arisen from a single family or a few families, such as we find among the anthropoids. The difference would therefore seem to lie in the fact that our society no longer repeats its earliest phylogenetic stage as does that of the social insects. But there are some insects, such as the honey-bee and some South American bees and wasps, that no longer repeat this incipient stage but from time to time send off new colonies, or societies by swarming, much as did the

Phoenicians and early Greeks and the nations of western Europe in more recent times.

(3.) Korzybski, in an interesting book entitled "The Manhood of Humanity," has recently endeavored to emphasize another difference, the existence of social heredity, or what he calls "time-binding," in human society and its absence among animals. Certainly no one can overestimate the importance of tradition and social heredity. We should still be in the anthropoid stage if we had failed to preserve and add to the capital of culture and mores transmitted to us by former generations or ceased to transmit them and the fruits of our own activities to our descendants. It is clear also that the social insects do not bequeath libraries, institutions and bank accounts to their posterity, and that each colony or society begins anew with the structural and instinctive equipment acquired by true, or organic heredity. This explains why we see so little change in these insects during the past 50 million years. Nevertheless, the distinction is not absolute. There are, as I shall show, ants, termites and beetles that cultivate fungi and bequeath them to succeeding generations. Social insects may also be said to bequeath real estate, that is, their nests, pastures and hunting grounds; and since the young queens of ants and termites often live for some time in the parental nests before they establish colonies of their own, there is reason to believe that they may acquire a very slight amount of experience by consorting with their sisters and parent queen.

(4.) It may be said that the social insects differ from man in not having learned the use of tools, but there are species of ants that use their larvæ as shuttles in weaving the silken walls of their nests, and the marvelous engineering feats of many social insects show that they are our close rivals in controlling the inorganic environment.

(5.) That they have acquired an equally astonishing control of their organic environment is shown by the fact that they are the only animals besides ourselves that have succeeded in domesticating other animals and enslaving their kind. In fact, the ants and termites may be said to have domesticated a greater number of animals than we have, and the same statement may prove to be true of their food-plants, when they have been more carefully studied.

(6.) It may be maintained that we have developed language and this, of course, is a true distinction, if we mean by language articulate speech, but the members of an insect society undoubtedly communicate with one another by means of peculiar movements of the body and antennæ, by shrill sounds (stridulation) and by odors.

The wonder has always been, not that there are so many differences in structure between such disparate organisms as insects and man, but that there are so many striking similarities in behavior. And the wonder grows when we find that social organization at least incipiently analogous to our own has arisen *de novo* on at least 24 different occasions in nearly as many natural families or subfamilies belonging to five very different orders of insects. A list of the groups that form these various societies is given in the accompanying table.

Coleoptera (Gynandrarchic)	1. Scarabæidæ (Copris, Minotaurus)
	2. Passalidæ (Passalus)
	3. Tenebrionidæ (Phrenapates)
	4. Silvanidæ (Tachigalia Beetles)
	5. Ipidæ (Ambrosia Beetles)
	6. Platypodidæ (Ambrosia Beetles)
Hymenoptera (Gynarchic)	*Sphecoidea*
	7. Sphecidæ (Sphex)
	8. Bembicidæ (Digger Wasps)
	Vespoidea
	9. Eumeninæ (Synagris)
	10. Zethinæ (Zethus)
	*11. Stenogastrinæ (Stenogaster)
	*12. Epiponinæ (Chartergus, Belonogaster, etc.)
	*13. Rhopalidiinæ (Rhopalidia, etc.)
	*14. Polistinæ (Polistes)
	*15. Vespinæ (Vespa)
	Apidæ
	16. Halictinæ (Halictus)
	17. Ceratininæ (Allodape)
	*18. Bombinæ (Bumble-bees)
	*19. Meliponinæ (Stingless Bees)
	*20. Apinæ (Honeybees)
	*21. Formicidæ (Ants)
Dermaptera (Gynarchic)	22. Forficulidæ (Earwigs)
Embidaria (Gynarchic)	23. Embiidæ (Embia)
Isoptera (Gynandrarchic)	*24. Termitidæ (Termites, or "White Ants")

In this list the first to tenth, the sixteenth and seventeenth, and the twenty-second and twenty-third are incipiently social or subsocial; the remaining ten, marked with asterisks, are definitely social. In the termites and all the beetle groups the colony consists of a male and female parent and their offspring of both sexes; in all the Hymenoptera, Dermaptera and Embidaria the female alone founds the colony, which is developed by her daughters. The former groups are therefore gynandrarchic, the latter gynarchic. These differences will become clearer as we proceed.

Let us examine first the six beetle societies which have been developed by species belonging to as many different natural families.

(1.) *Scarabæidæ*—For our knowledge of the habits of the dung-beetles we are indebted to one of the greatest entomologists, J. H. Fabre. His observations are recorded in parts of four of the ten volumes of his "Souvenirs Entomologiques," and comprise some of their most remarkable chapters. Some notion of the difficulties which he encountered while working out the life-histories of these insects may be gleaned from his statement that he did not succeed in completely elucidating the habits of one of them, the sacred Scarabæus, till he had had it under observation for nearly forty years. He studied quite a number of species and found startling diversity in their behavior. Some of them, the Aphodii, e. g., merely lay their eggs in fresh dung and the hatching larvæ feed on the substance. Among the others, which resort to much more elaborate methods of caring for their progeny, three different types of behavior may be distinguished:

(A.) The Sacred Scarabæus (Fig. 1) above mentioned and many allied forms are fond of the open sunlight and are often seen making perfect spheres of fresh cattle manure and trundling them away to cavities in the soil or under stones. These pellets are devoured by the beetles. Fabre found that a single beetle will not only eat but digest a mass of dung equal to its own body-weight in 12 hours. When the female beetle is ready to lay she makes a very similar pellet, but this time of sheep's dung and rolls it into an elliptical chamber which she has previously excavated in the

FIG. 1
Sacred scarabæi (Scarabæus sacer) trundling their pellet of dung. After E. J. Detmold.

soil. This chamber is about as large as one's fist. She then makes a crater-shaped depression surrounded by a circular flange at one pole of the pellet, lays a large egg in it and draws the material of the flange over it till it is completely enclosed. The pellet is now pear-shaped. Thereupon the mother beetle leaves the chamber and proceeds to dig another and provision it in the same manner. The hatching larva consumes the inside of the pellet, pupates

FIG. 2
Male Sisyphus beetle (*Sisyphus schæfferi*) holding the dung pellet while the female digs the burrow to receive it. After E. J. Detmold.

within it and emerges as a beetle in due season. There is, of course, nothing social about this insect. But in a smaller, allied form, *Sisyphus schæfferi* (Fig. 2), Fabre found that the male helps the female trundle her pellet to a convenient spot, guards it while she excavates a cavity, assists her in lowering the pellet, waits for her till she has oviposited in it in the same manner as the Scarabæus, and then departs with her to repeat the performance.

(B.) In Copris, of which Fabre studied two species, *C. hispanus* and *C. lunaris*, we have a closer approach to a social condition. These insects are crepuscular and dig a chamber as large as a large apple immediately under the pile of dung. This is then carried down in masses and leisurely devoured. During the breeding season, however, the beetles associate in pairs and the male and female not only cooperate in excavating a chamber but also in nearly filling it with dung, which they then proceed to knead into the form of a smooth ellipsoid as large as a turkey's egg (Fig. 3). In the case of *C. hispanus* the male then deserts the female and the latter proceeds to cut the ellipsoid up into four spherical pellets, each of which is treated like the pellet of the

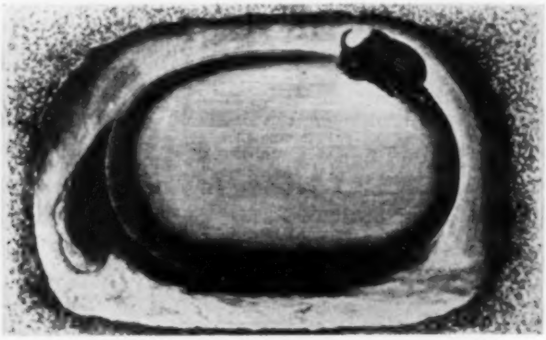

FIG. 3
Spanish Copris (*Copris hispanus*) fashioning her large ellipsoid of dung in her subterranean chamber. After J. H. Fabre.

sacred Scarabæus, provided with an egg and converted into a regular ovoid (Fig. 4). The mother remains in the chamber, guarding the pellets and keeping them free from fungus growth for four months, while the larvæ are developing within them. After the young beetles hatch the mother accompanies them to the surface of the soil and the family disperses. In the case of *C. lunaris* the male remains in the chamber with the female and helps her manufacture the ovoids, which owing to his assistance are twice as numerous as they are in *hispanus*. When the young beetles emerge they are escorted to the surface by both parents.

(C.) Other beetles, like Geotrypes, Onthophagus and Minotaurus, dig long tubular tunnels into the soil immediately under the dung. As a rule, they do not make spherical pellets but pack the deeper, blind end of the burrow with layers of dung till it forms

FIG. 4
Spanish Copris (*Copris hispanus*) guarding her ovoids of dung in the subterranean chamber. After E. J. Detmold.

a sausage shaped mass above the egg or enclosing it at one end. The behavior of *Minotaurus typhæus* (Fig. 5) is even more astonishing than that of Copris. The male and female beetles mate in March and together dig a tubular gallery straight down into the soil to the remarkable depth of five feet. The male remains above, works the dung up into elliptical pellets and lowers them down the shaft, while the female, after laying an egg in the sand at the bottom of the burrow, receives the pellets, tears them apart and packs the fragments down, as if she were working in a silo, till they form a mass as big as one's finger. Then she digs in succession a few branch galleries off from the main shaft, furnishes each of them with an egg and provisions it in the same manner. By constructing an ingenious apparatus and providing the beetles with an unlimited supply of manure, Fabre induced one male to make

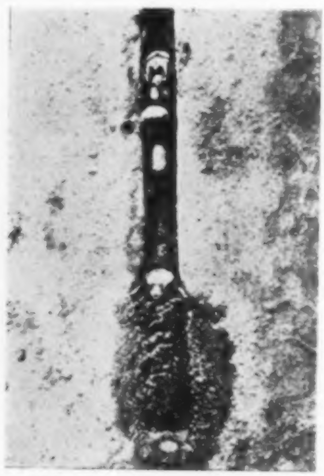

FIG. 5
Lowermost portion of burrow of the Minotaur (*Minotaurus typhæus*) showing the male bettle lowering the dung in pellets and the female storing it in layers above her egg. After J. H. Fabre.

239 pellets and hand them down to the female, but unfortunately the latter had died at the bottom of the gallery, so that there were no eggs and the pellets had not been torn apart and stored. The development of the young requires five months and the female very probably remains in the burrow till the brood hatches and crawls up to the surface.

(2.) *Passalidæ*—These large, active, jet-black, flattened and parallel-sided beetles (Fig. 6) are common throughout the tropics of both hemispheres. A single species, *Passalus cornutus*, occurs in the United States as far north as Michigan and Massachusetts. Ohaus, who first studied the habits of several species in the forests

of Brazil, has shown that they form colonies consisting of a male and female and their progeny and make large, rough galleries in rather damp, rotten logs. The broadly elliptical yellowish green or greenish black eggs, to the number of a dozen or more, are laid in a loose cluster and guarded by the parents. The larvæ are drab-colored and cylindrical, with the hind pair of legs reduced to peculiar short paw-like appendages which can be rubbed back and forth on striated plates at the bases of the middle legs (Fig. 7), thus producing a shrill note. On the dorsal surface of the abdomen of the adult beetle there is also a stridulatory organ in the form of patches of minute denticles which may be rubbed against similar structures on the lower surfaces of the wings. Ohaus found that the parent beetles triturate the rotten wood and apparently

FIG. 6
Passalus sp. Adult beetle and rather young larva, about twice natural size.

treat it with some digestive secretion which makes it a proper food for the larvæ, since their mouth-parts are too feebly developed to enable them to attack the wood directly. They are therefore compelled to follow along after their tunnelling parents and pick up the prepared food. All the members of the colony are kept together by stridulatory signals. The noise made by the beetles is so loud that it is possible to detect the presence of a Passalus colony in a log by merely giving it a few sharp raps. I have been startled on more than one occasion in Central America by the shrill response thus elicited from large Passali that were burrowing deep in the wood. When the larvæ are mature they pupate in the burrows and the emerging beetles are guarded and fed by the parents till they are fully mature. Observations that I have made in Australia,

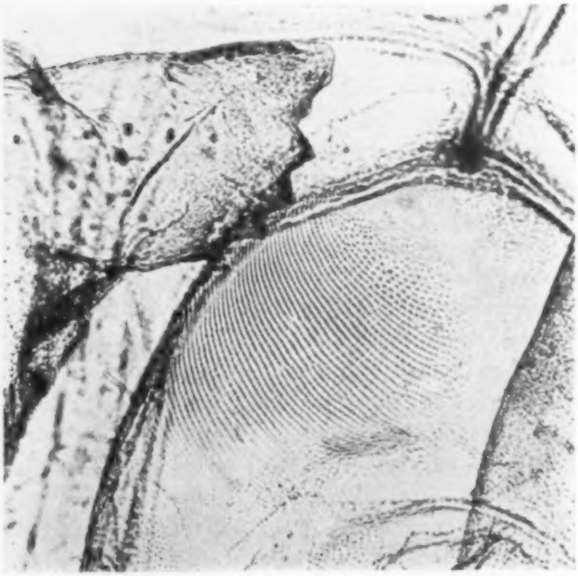

FIG. 7
Microphotograph showing abbreviated, paw-like hind leg of Passalus larva and the striated surface over which its toothed edge is rubbed during stridulation.

Central America, Trinidad and British Guiana confirm Ohaus's statements.

(3.) *Phrenapates*—Nearly a century ago Kirby described a

FIG. 8
Phrenapates Bennetti, a social Tenebrionid beetle, from a specimen in the Museum of Comparative Zoology. Photograph by Mr. Leland H. Taylor.

peculiar beetle from Colombia as *Phrenapates bennetti* (Fig. 8). It is about an inch long, jet-black and shining and superficially resembles Passalus, but belongs to a very different family, the Tenebrionidæ. G. C. Champion records it from Central America (Panama to Guatemala), and states that he "met it in plenty in decaying timber in the humid forest region of Chiriqui and frequently dug it out of cylindrical burrows, probably made by the larvæ, in the solid wood." Some years later Ohaus encountered the insect in Ecuador and gave a more detailed account of its habits. The male and female gnaw in the wood of the silk-cotton tree (Bombax) a narrow, cylindrical gallery about a foot and a half long and make roomy niches on each side of it at definite intervals. All the work is neat and smooth, unlike the burrow of Passalus. In each of the niches Ohaus found an egg or one or two larvæ, the latter feeding on fine, elongate shaving which filled the niches and had evidently been provided by the parent beetles. The eggs are laid at rather long intervals so that the larvæ, unlike those of Passalus, vary considerably in size. They resemble our common meal-worms (*Tenebrio molitor*), but are milk-white. No stridulatory organs could be detected in the beetles, but like some other Tenebrionids (Blaps) they emit a penetrating odor.

(4.) *Tachigalia Beetles*—During the summer of 1920 I discovered in the jungles of British Guiana a couple of Silvanid beetles which lead a more spectacular existence than some of the preceding. These beetles, which Messrs. Schwarz and Barber have named *Coccidotrophus socialis* and *Eunausibius wheeleri* (Fig. 9) are less than a quarter of an inch in length and have long, slender, subcylindrical, red or chestnut brown bodies, with short legs and club-shaped antennæ. They occur only in the hollow leaf-petioles (Fig. 10) of a very interesting tree, *Tachigalia paniculata*, and only in young specimens $1\frac{1}{2}$ to 7 ft. high while they are growing in the shade under the higher trees of the jungle. The older trees, which

FIG. 9
Tachigalia beetles, the larger *Coccidotrophus socialis*, the smaller *Eunausibius wheeleri*.

may attain a height of 40 feet or more, have all their petioles inhabited by viciously stinging or biting ants. Each beetle colony is started by a male and female which bore through the wall of the petiole, clean out any pith or remains of previous occupants it may contain and commence feeding on a peculiar tissue rich in proteins, which is developed in parallel, longitudinal strands in the wall of the petiole (Figs. 11 and 12). As they keep gnawing out this tissue they gradually make grooves and pile their feces on the ungnawed intervening areas, so that the interior of the petiole assumes a peculiar appearance (Figs. 13 and 14). While the beetles are thus engaged numbers of small mealy-bugs of the genus

FIG. 10

Bases of leaf-petiole of *Tachigalia paniculata* (*a*) of young, shade tree; (*b*) of large, sun tree, both nearly one-half natural size. Pieces of the older petiole and adjacent trunk have been cut out to show the cavity.

Pseudococcus (*Ps. bromeliæ*) (Fig. 15), covered with snow-white wax, wander into the petiole through the opening made by the beetles, settle in the grooves, sink their delicate sucking mouth-parts into the nutritive tissue and imbibe its juices. The beetles soon begin to lay their small, elliptical, white eggs along the edges of the grooves (Fig. 14) and the hatching larvæ, which are beautifully translucent, run about in the cavity and feed on the same tissue as the parents. But incredible as it may seem both the adult beetles and the larvæ in all stages have learned to stroke the mealy-bugs with their antennæ, just as our common ants stroke similar mealy-bugs and plant-lice, and feed on the droplets of honey dew,

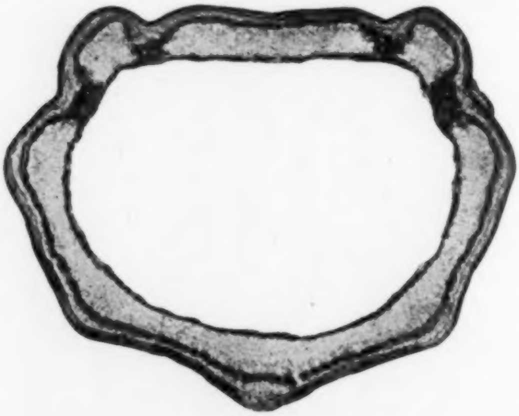

FIG. 11

Cross-section of base of a young, uninhabited petiole of *Tachigalia paniculata* showing the bands of protein-containing nutritive tissue (dark). Photograph by Professor I. W. Bailey.

or saccharine excrement which they give off when their backs are properly titillated. So greedy are the Silvanids for this nectar that I have seen a beetle or a larva stroke a mealy-bug for an hour or longer and receive and swallow a drink every few minutes. When two or more beetles or two or more larvæ or a group of beetles and larvæ happen to be engaged in stroking the same mealy-bug, they stand around it, like so many pigs around a trough, and the larger or stronger individual keeps butting the others away with its head. The butted individuals, however, keep returning and resuming their stroking till the knocks become too severe or the stronger individual leaves and begins to stroke another mealy-bug. Thus the beetles and their progeny have discovered a rich food supply, consisting in part of the proteid-containing tissues of the Tachigalia and in part of the sugar and water discharged by the mealy-bugs, which in turn imbibe the sap of the tree. The beetles lay their eggs at intervals so that larvæ in all stages are

FIG. 12
Enlargement of one of the bands of nutritive tissue of the preceding figure, showing the rather homogeneous protein-containing cells. Microphotograph by Professor I. W. Bailey.

found in the same colony. When mature each larva constructs a cocoon of minute particles bitten out of the plant tissues (Fig. 16), creeps into it, closes the opening from the inside and pupates. When the young beetles hatch they remain with their parents and

FIG. 13
Cross-section of Tachigalia petiole inhabited by a flourishing colony of *Coccidotrophus socialis.* The gnawed out areas of nutritive tissue are seen above, with the frass piled on the intermediate areas; below three cocoons have been sectioned. Photograph by Professor I. W. Bailey.

soon begin to lay eggs, so that eventually the colony consists of several dozen beetles, larvæ, pupæ and mealy-bugs in all stages and all living peacefully together, except for the little family bickerings of the beetles and larvæ over the milking of their patient, snow-white cattle. When the petiole becomes too crowded, pairs of young beetles leave it, enter other petioles of the same

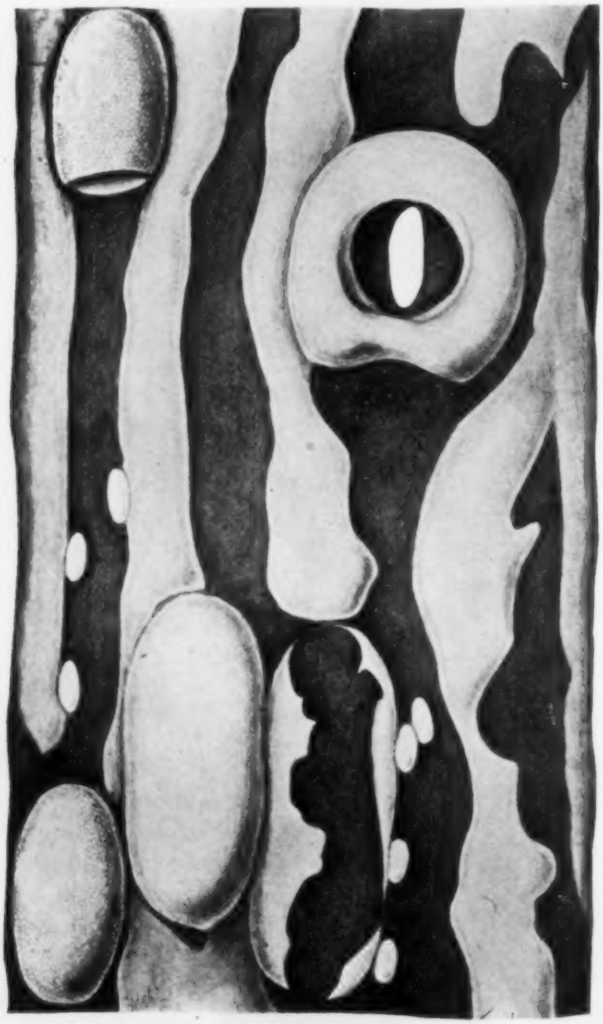

FIG. 14

Enlarged drawing of a part of the wall of a *Tachigalia* petiole inhabited by *Coccidotrophus socialis;* showing the food grooves and frass ridges, the entrance with its wall, the eggs, an intact and broken cocoon of the *Coccidotrophus* and two cocoons of the Coccid parasite, *Blepyrus tachigaliæ*, one of them after the eclosion of the parasite.

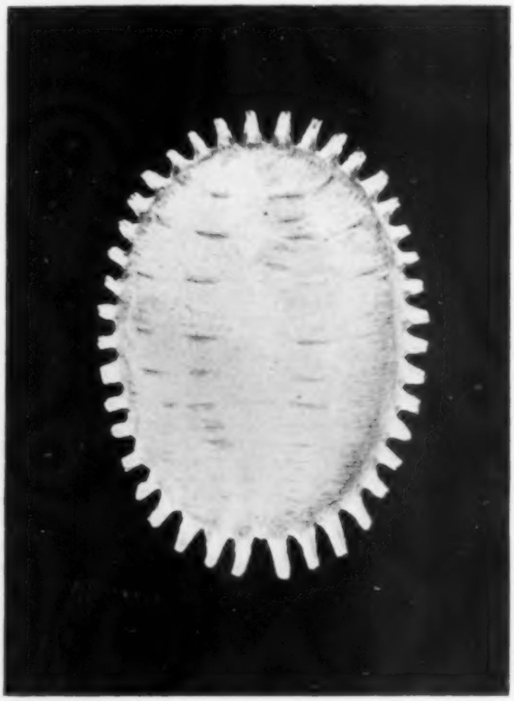

FIG. 15
Pseudococcus bromeliæ Bouché. Sketch of an adult living female with intact covering and peripheral pencils of wax.

or other Tachigalia trees and start new colonies. As the tree grows and emerges from the undergrowth into the sunlight, the ants which then take complete possession of it oust the beetles from the petiolar cavities but adopt their mealy-bugs, just as the invading German army appropriated the French cattle. There are many other extraordinary insects associated with the Tachigalia, its beetles and mealy-bugs, but I must omit an account of them because they are irrelevant to the present discussion.

(5.) *Ipid Ambrosia Beetles*—The family Ipidæ comprise small, cylindrical, red-brown or black beetles which live in the trunks and branches of trees. The group is now divided into two sections, one of which includes the bark-beetles, which are nonsocial and make the beautiful, radiating burrows so commonly seen on the inner surface of the bark of sickly trees, the other includes the ambrosia beetles (Fig. 17), which are social and run their burrows right into the wood of healthy or recently felled trees. The name "ambrosia beetles" is derived from a term applied by Schmidberger to the fungi which the beetles cultivate as food for themselves and their

larvæ. Structurally the two sections of the family Ipidæ can be readily distinguished by the mouthparts, the bark-beetles having their maxillæ armed with a row of 12 to 20 strong tooth-like bristles adapted to gnawing bark, whereas the maxillæ of the ambrosia beetles are fringed with 30 to 40 delicate, curved bristles, evidently suited to cropping the soft hyphæ of their food-fungus. Fourteen genera and nearly four hundred species of ambrosia beetles have been described. One genus alone, Xyleborus, which is cosmopolitan, contains 246 species. The fungi that grow in the galleries often

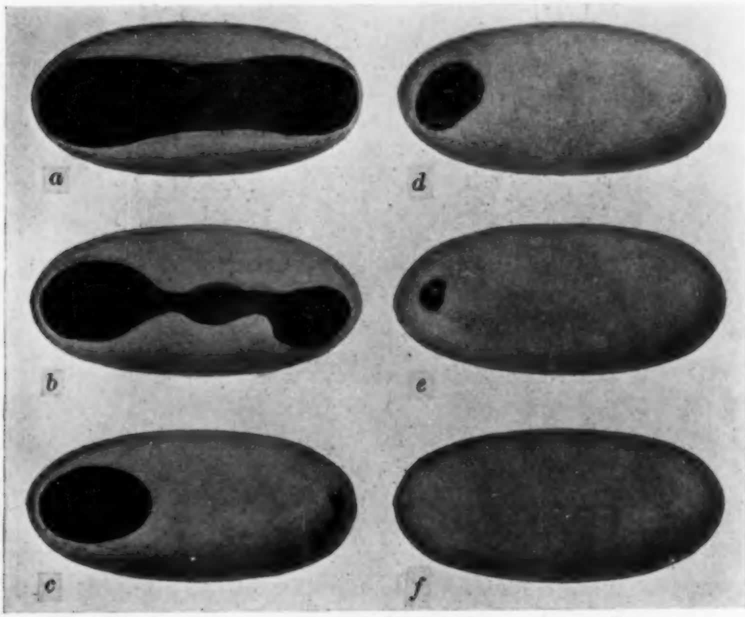

FIG. 16
Six successive stages in the construction of the cocoon by the full-grown larva of *Coccidotrophus socialis.*

give their walls a black stain, so that the value of the wood thus affected is greatly impaired. One species, *Xyleborus perforans*, has a bad reputation in the tropics, where it goes by the name of "tippling Tommy," because it has a strong predilection for boring in the staves of wine, beer and rum casks and thus causing much leakage. It might be adopted by our prohibitionists as their totem-animal.

The ambrosia beetles were first carefully studied in this country by H. G. Hubbard, whose untimely death deprived us of one of our most talented entomologists. I can not do better than quote his concise account of two of our species of Pterocyclon (*mali*

and *fasciatum*): "The sexes are alike, and the males assist the females in forming new colonies. The young are raised in separate pits or cradles which they never leave until they reach the adult stage. The galleries, constructed by the mature female beetles, extend rather deeply into the wood, with their branches mostly in a horizontal plane. The mother beetle deposits her eggs singly in circular pits which she excavates in the gallery in two opposite series, parallel with the grain of the wood. The eggs are loosely packed in the pits with chips and material taken from the fungus bed which she has previously prepared in the vicinity and upon which the ambrosia has begun to grow. The young larvæ, as soon as they hatch out, eat the fungus from these chips and eject the refuse from their cradles. At first they lie curled up in the pit

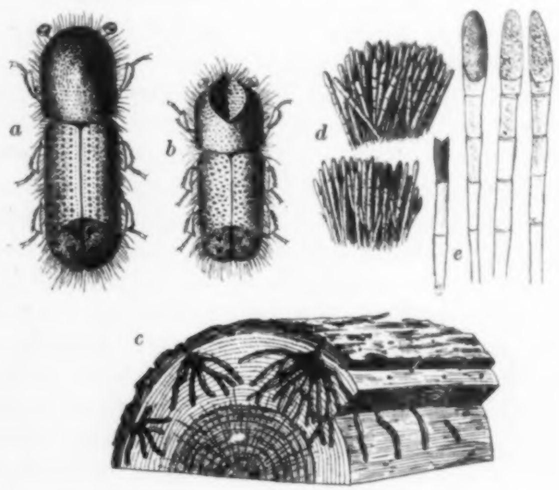

FIG. 17

Ambrosia beetle, *Xyleborus celsus* Eichh., of the hickory (after Hubbard); *a*, female beetle; *b*, male; *c*, piece of hickory, showing burrows of *X. celsus* in the sap-wood; *d*, ambrosia grown by *X. celsus* on the walls of of the burrows; *e*, same more enlarged.

made by the mother, but as they grow larger, with their own jaws they deepen their cradles, until, at full growth, they slightly exceed the length of the larvæ when fully extended. The larvæ swallow the wood which they excavate, but do not digest it. It passes through the intestines unchanged in cellular texture, but cemented by the excrement into pellets and stained a yellowish color. The pellets of excrement are not allowed by the larvæ to accumulate in their cradles, but are frequently ejected by them and are removed and cast out of the mouth of the borings by the mother beetles. A portion of the excrement is evidently utilized to form

the fungus bed. The mother beetle is constantly in attendance upon her young during the period of their development, and guards them with jealous care. The mouth of each cradle is closed with a plug of the food fungus, and as fast as this is consumed it is renewed with fresh material. The larvæ from time to time perforate this plug and clean out their cells, pushing out the pellets of excrement through the opening. This debris is promptly removed by the mother and the opening again sealed with ambrosia. The young transform to perfect beetles before leaving their cradles and emerging into the galleries.'' The ambrosia of Pterocyclon ''is moniliform and resembles a mass of pearly beads. In its incipient stages a formative stem is seen, which has short joints that become globular conidia and break apart. Short chains of cells, sometimes showing branches, may often be separated from the mass. The base of the fungous mass is stained with a tinge of green, but the stain of the wood is almost black.

(6.) *Platypodid Ambrosia Beetles*—These were formerly included among the Ipidæ but are now regarded as an independent family. They can be easily distinguished by their much broader head and longer feet, the first joint of the tarsi being as long as all the remaining joints together. The great majority of the species are tropical, so that their habits have not as yet been very thoroughly studied. So far as known, the Platypodids all bore in the wood of dying or recently felled trees, live in societies and feed on fungi which they grow on the walls of their burrows. Hubbard and Swaine have studied some of our North American and Strohmeyer has published some observations on one of the few European forms. The following description of *Platypus compositus* is quoted from Hubbard: ''They are powerful excavators, generally selecting the trunks of large trees and driving their galleries deep into the heart-wood. They do not attack healthy trees but are attracted only by the fermenting of the sap of dying or very badly injured trees. The death rattle is not more ominous of dissolution in animals than the presence of these beetles in standing timber. . . . The female is frequently accompanied by several males and as they are savage fighters, fierce sexual contests take place, as a result of which the galleries are often strewn with fragments of the vanquished. The projecting spines at the ends of the wing-cases are very effective weapons in these fights. With their aid a beetle attacked in the rear can make a good defense and frequently by a lucky strike is able to dislocate the outstretched neck of his enemy. The females produce from 100 to 200 elongate-oval pearl-white eggs, which they deposit, in clusters of 10 or 12, loosely in the galleries. The young require five or six weeks for

their development. They wander about in the passages and feed in company upon the ambrosia which grows here and there upon the walls. . . . The older larvæ assist in excavating the galleries, but they do not eat or swallow the wood. The larvæ of all stages are surprisingly alert, active and intelligent. They exhibit curiosity equally with the adults, and show evident regard for the eggs and very tender young, which are scattered at random about the passages, and might easily be destroyed by them in their movements. If thrown into a panic the young scurry away with an undulatory movement of their bodies, but the older larvæ will frequently stop at the nearest intersecting passage and show fight to cover their retreat." The ambrosia *of P. compositus* consists of hemispherical conidia growing in clusters on branching stems. The long continued growth of this fungus blackens the walls of the older galleries.

Each species of ambrosia beetle—and this is true of both the Ipidæ and the Platypodidæ—grows its own peculiar fungus in a pure culture, irrespective of the tree it may select for its burrows. Strohmeyer seems to have shown how in the case of certain Platypodids the mother beetle manages to obtain the spores of the particular fungus which she cultivates. He finds that she carries them from the burrows in which she passed her larval and pupal stages to the new burrows which she makes for her own progeny in a kind of crate or basket consisting of one or several dense tufts of long, curved hairs on the top of her head or on her mouth-parts; and Schneider-Orelli has found that the females of the Ipid ambrosia beetles carry the fungus in the fore part of the stomach and are thus able to infect the walls of the new burrows which they establish. These are only two of the instances among the social insects of the actual transmission of a food-plant from generation to generation.

We may now summarize very briefly the main points of interest in connection with the social beetles:

(1.) The six unrelated families are all very ancient. Species of four of them (Silvanidæ, Tenebrionidæ, Ipidæ and Platypodidæ) are, in fact, known from the Baltic Amber. The absence of the dung-beetles from that formation is easily explained, since these insects are not arboreal, nor are they attracted by liquid resins. Several of the living genera (Scarabæus, Copris, Onthophagus, Sisyphus, and Gymnopleurus), however, are known from the Upper Miocene shales of Oeningen, and Hagedorn mentions several species of ambrosia beetles as occurring in the African and Malagasy copal, a fossil resin of comparatively recent formation. There can be little doubt that all the six families which I have been consider-

ing are much older than these records would seem to indicate. Most of them, in fact, are cited by Handlirsch as probably having arisen at the beginning of the Cretaceous or even earlier.

(2.) The substances on which the six groups of social beetles feed are remarkably diverse, ranging from dung and wood in various stages of decay to the living tissues of plants, the honey-dew of mealy-bugs and delicate fungi. These are all abundant and ubiquitous substances of vegetable origin, and all the social beetles manage to store or find their food in such peculiar places that they can avoid intense competition with most other organisms.

(3.) This abundant but in many cases not very nutritious food-supply which the adult beetles seek and exploit primarily for their own consumption enables them to acquire a considerable longevity, and this in turn, of course, enables them to survive the hatching and development of their young.

(4.) In all the groups the parent beetles show a very pronounced interest in their offspring, and feed them directly or, at any rate, place them in close contact with the food and guard them.

(5.) The father beetle cooperates to a greater or less extent with the mother beetle in providing for the young, although his cooperation may be slight. Probably it is really *nil* in most of the Ipid ambrosia beetles, the males of which are in many species wingless and very rare, so that mating must take place in the maternal colony.

(6.) There are neither structural nor physiological differences between the fully developed young and the adult parents of the social beetles. In other words, nothing like a development of castes has made its appearance among them.

HOMING POWERS OF THE CAT

By Professor FRANCIS H. HERRICK
CLEVELAND, OHIO

NO animal has been so highly extolled on the one hand as a paragon of virtue, and on the other so roundly condemned as an unmitigated nuisance as the domestic cat, which has been associated with man for upwards of three thousand years. Southey once declared that no home was complete unless it had "in it a child rising six years and a kitten rising six months." Friends of the cat never tire of lauding its domesticity, its neatness, its useful services as a destroyer of rodents, the natural grace and beauty of its movements, its affection and even its surpassing intelligence; while its detractors denounce it as an independent, unsocial ingrate, attached to the hearth for the comfort it affords, but seldom wasting any affection on the person who lays the fire or supplies it with food, as incapable of any unselfish devotion and service, a carrier of vermin and disease, and the most cruel and remorseless enemy of bird-life everywhere.

Viewed impartially the cat is a carnivorous animal of rather moderate intelligence; courageous and resourceful when put to the test, it only follows at all times the bent of its strongest instincts; like every feline it has keen tactual, visual and auditory senses, but its nose is small and rather weak; its endurance in relation to its bodily strength is phenomenal, and we can not but admire its marvellous powers of muscular coordination and control; fecund, and endowed with a vitality which in the popular mind extends far beyond life's usual limits, the cat is unsurpassed as mother and nurse, and in this field her instinct is never-failing.

In his excellent economic study of the cat, Forbush[1] reminds us that while partly tamed this animal has not been fully domesticated: "It has not been subdued, confined or controlled, except in rare cases, but is to all intents and purposes a wild animal. In most cases it stays in the home of man, mainly because of the warmth of his fire, the food that it eats and its affection for the location where it was reared. If, by accident or design, anything

[1] Forbush, Edward Howe: "The Domestic Cat," *Economic Biology Bulletin*, No. 2. Boston, 1916.

occurs to interrupt its association with man, it readily returns to the wild;" and Shaler,[2] who is also quoted by this writer, says: "As a consequence of the affection which cats have for particular places, they often return to the wilderness when by chance the homes in which they have been reared are abandoned. Thus in New England, in those sections of the district where many farmsteads have of late years been deserted, the cats have remained about their ancient haunts and have become entirely wild. In this state they are bred in such numbers that their presence is now a serious menace to the birds and other weaker creatures of the country. The behavior of these feralized animals differs somewhat from that of creatures which have never been tamed. They have not the same immediate fear of a man, but the least effort to approach them leads to their hasty flight."

Every one will admit that the cat varies no less in its individual ways and disposition than does its inveterate enemy, the dog, yet its attachment is mainly directed to its home and neighborhood, and while vagabondage may be rarely adopted by choice it is more commonly enforced. "Thousands of families, says Forbush, "go into the country or to the seaside in summer, taking cats and kittens with them, and leave their pets on their return to the city, not knowing, perhaps, that such cruelty is forbidden by law."

Varied and voluminous as the literature of the cat is found to be, especially in the fields of anecdote, general natural history and anatomy, its homing ability has never been previously tested under experimental conditions, though accounts of this notorious power abound in many languages; from time immemorial it has been said that the cat, like the bad penny, always comes back. Probably all cats possess this homing power in varying degrees, and all with fixed abodes might possibly be induced to exercise it under certain conditions; yet in every case the possession of a power, and the tendency to use it should be clearly distinguished; though possession, in this case, be under the firm grasp of heredity, the *use* is determined by experience and the physiological state of the animal at the moment. Thus it is obvious that an animal with dependent young would have a double inducement to return to its home provided local attachments had already taken root; on the other hand, it is equally clear that, whenever an animal is forcibly removed from its abode, the diversions or accidents which are likely to attend it may be of such character as to block or defeat any impulse to return. In every such case the only facts likely to be either known or knowable are that the animal on that occasion did or did not return; we are usually left in complete ignorance of the animal's

[2] Shaler, Nathaniel Southgate: *Domesticated Animals*, New York, 1895.

inherent abilities, of its struggling impulses or even of its efforts, should any be made.

The account of experiments to follow is offered mainly as a sample of this animal's power under certain conditions; they do not admit of the usual methods of control; they can be multiplied indefinitely, but they can not be exactly repeated, since the variables in each case, of which fear is but one, can not be predicted and are bound to influence response.

The mother of the first cat with which we experimented was brought to us in a basket from a town ten miles distant, and never left us until the following year, when she began to raid the birds on our premises and was given away; her offspring, to which I shall now refer, was born and reared on our place and, so far as we knew, it had never left it; at the time of which I speak it certainly had not shown any roaming propensities. The first six weeks of this kitten's life was spent in the barn, where it received little or no attention, and became so wild that it scarce could be handled with impunity. Shortly after this the mother began to bring it into the house; she always entered by a glass-door, which opens to a piazza at the rear, and soon formed the habit of scratching at the glass whenever she wished to be let in or out. The kitten soon acquired the same habit and lost its wild ways completely; in time it became a handsome home-loving house-cat, and we were sorry to part with it, but at the age of fifteen months, when we had to choose between its companionship and that of any nesting birds upon our grounds, its banishment became inevitable.

The first experiment casually made with this cat led me to suspect that it was impossible to turn some Thomases around, and I determined to investigate this point further at the first good opportunity. This cat was taken in a gunny-sack over an irregular course, mainly by electric car, down a series of hills to a point on the University Campus in the city of Cleveland, 4.6 measured miles from its home in Cleveland Heights; there it was given a dish of milk and the liberty of two rooms, in one of which a window had been slightly lowered at the top. This was on the morning of a Monday, and at five o'clock in the afternoon it seemed to be quite at home in its new quarters; on Wednesday morning, about forty hours later, it suddenly appeared on the back porch of our house and gave its usual signal to be admitted. In order to reach its home this cat had traversed an unknown country, consisting of city or suburban streets and allotments, had crossed the gulley of the Belt Line railroad, probably by one of its bridges, and ascended in the path of greatest resistance a series of terraces to a height of four hundred feet. That its home neighborhood could have been

reached by exploratory movements, on the trial and error order, or by chance alone seemed highly improbable; the only known facts were that it made a homing attempt and succeeded.

When we tried to have this cat repeat its performance in the daytime it would not voluntarily leave the building, and even when set on the ledge of an open window it would quickly drop back to the floor; it was finally left in some shrubbery outside, and when I was called away for a brief time it disappeared and was not seen again. Regretting the loss of this cat through our failure to keep it under continuous observation, we decided to test the homing power, at the next opportunity, in the following way: (1) to take the cat, as before, under such conditions that the possibility of orientation through the receptors of sight, hearing and smell would, in all probability, be completely eliminated; (2) to convey it successively in different directions, and gradually increase the distance at each test, and (3) to release it at a uniform time at dusk, in unknown territory, and under conditions of as free behavior as it was possible to obtain.

The experiments to follow were made with another individual, a female with kittens which were about ready to be weaned; she had been adopted by a neighbor, and her previous history was not known; she was a large and powerful animal (See Fig, 1) and had

FIG. 1

This cat returned to its home seven times in succession when taken out blindfolded, by automobile, over distances of one to three miles; in the first four tests in the direction of the cardinal points, and in one instance after being put under complete anesthesia.

become such an inveterate hunter of birds and young chickens that her life had been declared forfeit. This cat could not be trusted for a moment when the chicks were about, as my neighbor observed when one evening he tried to entice her from the barn with a dish of fresh milk; thinking, however, that they would be safe as long as we stood by, a brood was released; the cat came to call, but was no longer interested in milk; like a flash she snapped up a chick from under our noses and made off with it to the barn; and this was the third victim of that day. I mention the incident to show how well this animal was able to take care of itself; whatever its history might have been, an experiment to follow proves conclusively, I think, that it had never been a vagrant over those parts of the country to which it was soon to be introduced.

Seven successive returns were made by this cat from points varying from one to three miles from its home, on June 4-23 (See table); she was secured in a sack, carried to the release station by motor-car, and placed under a wooden box which was weighted with

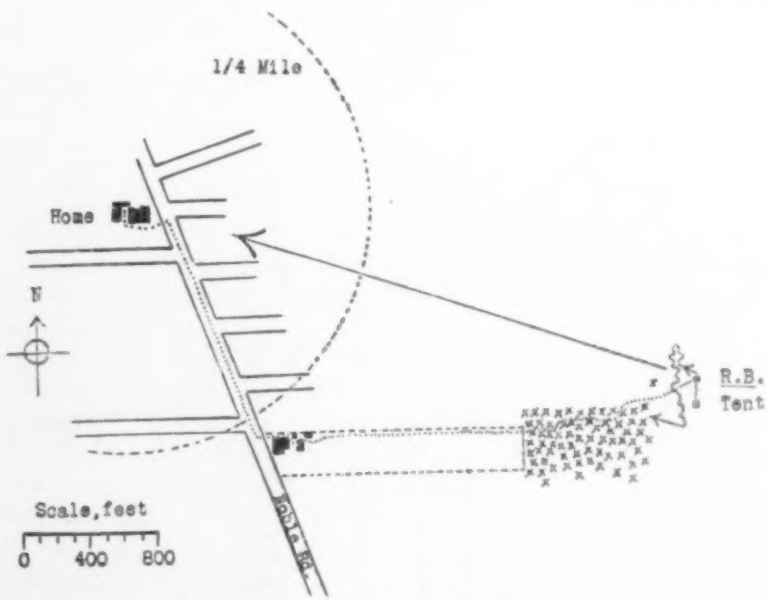

FIG. 2. HOMING OF CAT: EXPERIMENT NO. 2

Home-territory conventionally indicated by circle of one-fourth mile radius. Cat taken blindfolded one mile on course, marked by dotted line, to release-box, R. B. Long arrow marks direct course from release station to center of home-territory; path of cat after release indicated by arrows and irregular line; cat oriented correctly and started in the home-direction, but later reversed her course and made for the cover of woods (crosses) when disturbed by dogs; animal under observation 35 minutes after release. Cleveland Heights, Ohio: June 4, 1920.

stones; the box was raised at the moment of release by a cord operated from a green observation-tent 75-100 feet away; (See Figs. 2 and 3) the cat was given its freedom at about the same time in the evening, and the box was opened towards the north in every experiment except number 4, in which the opening was to the east; we wished to ascertain (1) whether the cat would continue to return to home and kittens when taken at varying distances beyond its known or probable range; (2) whether under such conditions it would orient immediately and correctly; (3) whether after making a correct orientation it would strike off in a *direct line* for its home and pursue that course, or whether it would be mainly concerned with cover and safety first. In tabulating these tests the homing time in all but one instance was less than the estimate given; it could not usually be exactly ascertained; thus if the cat was set free at eight o'clock of an evening, and was found with her kittens again at six on the following morning, the time is given as "10 hours (minus)"; she might have stolen in at any time during the night, and on one occasion was detected at two o'clock in the morning, the probable time of her arrival.

In the first four tests (Nos. 2-5 of the table) the cat was taken

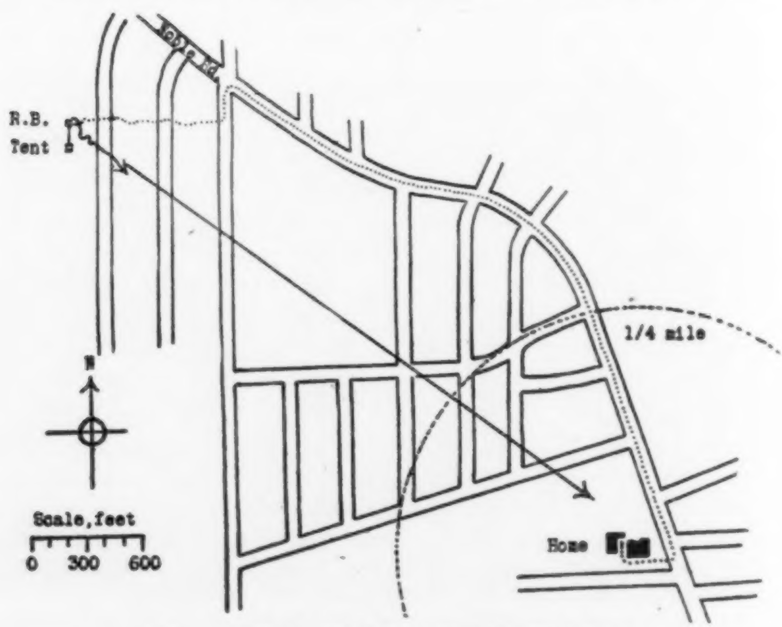

FIG. 3. HOMING OF CAT: EXPERIMENT NO. 5

The cat oriented correctly upon release, and moved undisturbed in a direct line for its home until lost to view; animal under observation six minutes after release. See table for further details; designations as in Fig. 2. Cleveland Heights, Ohio; June 18, 1920.

HOMING POWERS OF THE CAT: RECORD OF EXPERIMENTS

No.	Date	Distance in miles	Station of release	Time of release	Time of return	Homing time in hours
1		4.6 (west)	Campus W. R. Univ. Cleveland	Monday in evening	Wednesday following, 10 A. M.	38 (about)
2	June 4	1 (east)	Open field, 400 ft. from woods	7:25 P. M.	Between 11:30 P. M. Jn. 4 and 7:30 A. M. Jn. 5	8 (minus)
3	June 9	2 (west)	Open field, 150 ft. from highway	8:05 P. M.	Before 6:30 A. M. Jn. 10	10 (minus)
4	June 10	3 (south)	Open field, 900 ft. from highway	7:45 P. M.	2 A. M. Jn. 14	73
5	June 18	1 (north	Unoccupied allotment	7:55 P. M.	Before 6 A. M. Jn. 19	10 (minus)
6	June 21	1 (east)	Same as in No. 2	7:30 P. M.	Before 6 A. M. Jn. 22	10 (minus)
7	June 22	1 (east)	Same as in Nos. 2 and 6	7:55 P. M.	Before 7:30 A. M. Jn. 23	11 (minus)
8	June 23	1½ (east)	Ploughed field, 200 feet from highway	7:30 P. M.	Before 7:30 A. M. Jn. 26	60 (minus)
9	June 30	16½ (east)	Willoughby, Ohio	6:35 P. M.	No return	

Experiments Nos. 2-9 were made with the same cat; in Nos. 6 and 7 place of release the same as in No. 2; in No. 8 the animal was anesthetized before being taken out; in all cases the cats were blindfolded and taken a measured distance by electric car or automobile.

in the direction of the cardinal points, to distances of 1, 2, 3, and 1 miles respectively, not because we supposed the cat to have any interest in the compass, but simply for convenience in dividing up the available area; we had in mind also the obvious fact that an animal like the cat is liable to establish habits of roaming farther from its home in certain directions than in others, so that any area familiar to it might be described by a very irregular curve, the radii extending half a mile or possibly more in certain directions, or but a few rods in others. In each of these experiments the cat jumped from under the box, as if in response to an electric shock; in every case she oriented correctly to her home region, and started to move in its direction; in one instance (See Fig. 3 and No. 5 of table) she not only started but continued at a rather rapid pace toward home until lost to view, and in this case the right course took her past the tent. It was thus positively shown that there was no necessary backtracking over the course that was followed by the automobile in bringing her out. In the other three cases when the cat had moved but a few yards in the home direction, and then suddenly veered and sought cover in fence-rows or woods,

we found that one or more persons had seen our tent and were moving towards it. The homing time, as pointed out above, could not be accurately determined in the first, second and fourth of these tests, but was probably from four to ten hours; over the course of three miles (No. 4 of table) 78 hours were required.

In the first test (See Fig. 2) the cat sprang from under the box, came to attention, as it were, for a moment, facing in the direction of her home region, which lay a few points north of east; she moved slowly for a short distance on this course, mewing almost continuously, then turned more to the north, and after going a few rods suddenly veered and made for cover in a piece of woods, four hundred feet to the south, passing within a few yards of our tent. At this juncture a farmer's boy appeared on the scene with two dogs, which were soon on the trail, but she out-distanced them and in a moment was safe in a tree; here we left her to her own devices, and all that we knew of her subsequent movements was that by six o'clock on the following morning she was again at home with her kittens. That she returned the same night, and with little delay, is most probable. The grass in the field where this test was made was not at that time very tall, and the cat could be readily seen by one standing erect; whether the bend in the curve marks the point at which the cat first sensed the approach of the boy and the dogs may be doubtful, but there is no doubt that this change in her course was due to a sudden impulse to find cover.

In the second experiment of the series the animal was taken on June 9 over a distance of two miles to a point due west, and 1 2/5 miles in air-line from its home; the tent was placed in a cornfield, one hundred and fifty feet from the highway, along which automobiles and pedestrians were liable to pass, though rather infrequently: the box was opened towards the north, as before, and the cat, when free, could move in any direction but south without passing the tent, her home-course being a point or so north of east; at the moment of release she oriented perfectly and began moving in the right direction, but as in the previous test she soon swerved to the north; at that moment also two men, who were coming down the street, stopped and made a movement as if to approach the tent; after traveling northward for about a rod, in consequence, as I believe, of this disturbance, the cat stopped, cocked her ears, glanced back at the tent, struck the home-course again and began moving rapidly up the steep hillside; she continued in the direct line for home until lost to view at 8:25 P. M., when it was quite dark; the cat had been under observation twenty minutes, and I believe made her home rather promptly, but she was not seen again until the morning following.

On the very next day this cat was subjected to a more difficult test; she was taken in the usual way over a course three miles to the south, and the tent was pitched nine hundred feet from the road in the hope of avoiding all interference; the release-box was set ninety feet away at the bottom of a run, on ploughed land, and opened eastward, north being the true course home; on this side, seventy-five feet away was a fence, with woods stretching beyond, and at about the same distance south was an unfenced stand of thick grass, while some three hundred feet to the east lay a stone wall bordered with small trees; as before the cat came out with a bound, oriented aright, and moved a few yards on the homeward line; then, as in the two previous tests she wheeled about and travelled in an opposite direction, this time entering the tall grass; in this instance the disturber of the peace was the owner of the land, who had doubtless seen us placing the tent; his approach coincided with the cat's move for cover, and as we stood watching her she gradually worked over to the easterly fence-row. This was at 8 p. m., June 10; at two o'clock in the morning of June 14, or 78 hours later, the mewing of this cat was heard under a window which opened on the lawn of its owner; this, as we had reason to believe, actually marked the hour of the cat's return.

In the fourth and in some respects the most interesting test (See Fig. 3 and No. 5 of table) we carried the cat by motor-car one mile north by east, turned into another road, and placed the tent on newly allotted land two hundred and fifty paces from the highway, and for once succeeded in avoiding all interruptions. The box was opened to the north at exactly 7:55 p. m., the home direction being a few points east of south. As in former tests the cat came out with a spring; she oriented correctly without the slightest hesitation, and at once began moving in a direct line for home; she advanced slowly, paused a number of times, and stood with ears cocked, as shown in the photograph, but never once turned from the chosen course during the six minutes that we were able to keep her under observation; she finally disappeared in a dry water-course which came from the hillside above; there can be little doubt that she made home in good time although she was not detected until early the next day.

The two experiments which followed (Nos. 6 and 7 of table) were merely repetitions of the first, and were undertaken as a check upon this test—to ascertain whether the behavior would be similar in each case, and if the homing time would be improved. In the first of these the cat got free prematurely, took the wrong initial direction, and was soon lost to view in the grass, which by that time had grown quite tall. In the next trial (No. 7), at the mo-

ment of release, she started on the wrong course, but in a moment oriented correctly, and was on the homeward path when she disappeared from sight. In neither case could we determine the time of the cat's arrival, but in all probability she made home the same night.

We have already referred to the fact that many cats revert to the wild or semi-feral state, vagabondage being sometimes adopted by choice, or more commonly it is forced upon them by the neglect of their owners. Had the second cat been a nomad of this character, and in the region about its present home, the experiments just described would have no value as tests of its homing abilities; the whole region for miles around might have been familiar ground. That the territory embraced in these tests was actually new to this animal is, I believe, clearly indicated by the next experiment; the cat was now put under complete anesthesia by chloroform, and conveyed by motor-car, as before, 1½ miles east by north of its home-site; somewhere towards the end of the journey she recovered from the anesthetic so as to appear quite able to take care of herself when let out of the bag; the animal was accordingly set free, without using the blind, in a field fifty feet from the highway; she made at once for this road, in a direction opposite that of her home, and would have gone beyond it but for a gorge which blocked her path; then she moved beside the road, very nearly back-tracking for several rods over the course which the automobile had taken, and disappeared in the cover of bushes. She returned home, as in all the previous experiments, but only after an interval of 60-70 hours; that is, to home under these conditions from a distance of 1½ miles, which ordinarily was accomplished the same night, or at most in from eight to ten hours, now required eight times as long. This could hardly have been the case if the cat had awakened to find itself in familiar territory. To hazard a conjecture I am inclined to believe that in this case the cat, finding itself on strange ground, with all relations with its home-region broken, wandered about until its lost orientation was by chance restored through the discovery of familiar objects.

At this stage in our experiments the cat had accounted for so many chickens that its owner was anxious to be finally rid of it; but it had proved so good a "homer" I felt that it had fairly earned its freedom; accordingly it was decided to take a long chance, and it was liberated in Willoughby, Ohio, 16½ miles from its home, at a point three miles north of the second bridge which crosses the Chagrin River in that section; we hope that it found a good home, where its bird-killing propensities could be more effectively checked; it never returned. It does not necessarily follow that the distance

and other obstacles in this test were too great for this cat's remarkable homing ability, for the longer the course the greater the number of diversions or accidents liable to be encountered; moreover this cat's kittens had now been weaned, and the longer the attempt to home is protracted or delayed the weaker becomes the impulse to return, and the greater the chance afforded for new habits to develop and replace the old.

Possibly most of the stories of cats and other animals returning to their homes from long distances, when not composed in newspaper offices, are exaggerated, or based on inexact identification. As an instance of the latter sort, Claparède[3] mentions the story of a cat taken from Montilier on the shore of the lake of Morat to Lausanne, a distance of 50 kilometers (about 31 miles), and said to have returned the following day to its old home, a statement ample in itself to refute the account; an investigation, moreover, by Emile Yung, Professor of Zoology at the University of Geneva, proved that the cat had never left Lausanne, the one seen at Montilier being another individual of the same size and color. Claparède, however, records on reliable testimony the case of a cat carried in a basket 18 kilometers (11 1/5 miles) by rail to Geneva, and afterwards returning to its former home at Céligny. In a characteristic "Souvenir" Fabre[4] has told the story of the cats, which accompanied him and his family whenever he was obliged to change his domicile; in going by carriage from Orange to Sérignan, a distance in straight line of 4⅜ miles, the oldest cat was confined in a basket, and upon arrival it was made a prisoner for a week in the hope that it would become habituated to its new abode; but all to no purpose, for upon regaining its freedom it returned at once to Orange. When found at its former home the animal was wet to the skin, and its body was smeared with red earth, an evidence, as Fabre thought, that it had crossed the Aygues, a tributary of the Rhone, and afterwards gathered up the dust of the fields; it was May, he said, and there was no mud; two bridges cross this stream one at a point above, and the other below, the course the cat must have followed; but, said Fabre, it took neither, its instinct directing it home by the shortest course, and it even overcame its repugnance to water in order to reach its beloved abode. Upon similar evidence Fabre concluded that another of his cats had returned by crossing the river Sorgue, at Avignon, where it avoided the bridges in order to follow the more direct route.

[3] Claparède, Ed.: "La Faculté d'Orientation Lointaine," *Archives de Psychologie*, ii: pp. 133-180, Geneva, 1903.

[4] Fabre, J.-H.: *Souvenirs Entomologiques*, ii, pp. 124-133, Paris.

Hodge[5] records an interesting experiment with a large tomcat, which he and his friends took with them in a boat one dark summer's night, on a lake at Madison, Wisconsin; after a time, says Hodge, the cat became very restless and anxious to go home; he would climb out to one end of the boat, and stretching his head towards home, mew almost continuously. Hodge and his friends then amused themselves by turning the boat slowly round and round, first one way and then another, to see if they could throw Tom off his bearings; but all to no purpose for, says Hodge, "whether right side, left side, bow or stern, Tom was always on the part of the boat nearest home, and straining as far as he could in that direction. Fully a mile from any shore, how could he tell which shore was which?" But few lights were visible on the shore, and none of the party was able to distinguish their own cottages. They then wrapped Tom in a heavy blanket-shawl, and held him first on the lap and then flat on the bottom of the boat, while it was turned round as before; but whenever released, the cat started "with never a mistake and without the slightest hesitation towards the end of the boat nearest home. Whether the boat was turned by a single stroke, as on a pivot, or rowed slowly around in a circle, the result was always the same. Members of the party were blindfolded and required to guess whether the boat was turned or allowed to stand still, or was rowed in a straight line or in a circle; and it was an even chance whether they guessed right or wrong." The tomcat kept his bearings better than any of them. Hodge was inclined to believe that the cat's direction-constant was its sense of hearing and its ability to detect sounds on shore which were too faint for the human ear.

From the experiments recorded above, though few in number, I think that we are justified in drawing the following conclusions: (1) That the returns in experiments 1-5 and 8 were made from unfamiliar territory; (2) That in the tests 1-5 success did not depend upon chance; (3) That the cat did not return over the course taken by the motor-car on the journey out, or according to a so-called "law of reversal" (*loi du contrepied*), as suggested by Darwin, and revived by Bonnier and Regnaud; (4) That the homing power in a more or less direct line is independent of the sense-receptors of vision, hearing and smell; (5) That under the conditions described the cat is able to home at night, and probably does so by preference; (6) That its power of return is not affected by rotation or any ordinary treatment, barring possibly anesthetization, which the animal may receive, prior to or during the journey to the point of liberation.

[5] Hodge, C. F.: "The Method of Homing Pigeons," *Pop. Science Monthly*, Vol. 44, New York, 1893-94.

The problem of homing or of "distant orientation" in the higher animals is very ancient, and the literature of the subject, particularly as concerns the carrier pigeon, is voluminous and vexed to the last degree. Claparède in 1906 reviewed the whole field, and discussed the various theories to which the question of homing has given rise; again in 1915 Watson and Lashley[6] gave a résumé of the whole question in vertebrates, and a concluding account of their remarkable experiments on the homing powers of the Noddy and Sooty Terns; they showed that many of these birds when taken from their nests on Bird Key, Tortugas, Florida, and carried upwards of 800 miles in various directions at sea, made successful homing flights; their birds were untrained; they returned from territory through which they had apparently never passed, and over the open ocean, which could afford no landmarks, visible at least to the human eye. Their results, though admittedly negative, disproved certain theories of homing; they found no "special tactual or olfactory mechanism situated in the nasal cavity," which might function for distant orientation, but thought it "just possible" that the terns might "possess on certain parts of the body (eye-lids, ear covering or oral cavity) sensitive tactual and thermal mechanisms which might assist them in reacting to slight differences in pressure, temperature and humidity of air-columns."

We are now concerned only with the powers of an animal standing low on the ground, and moving rather slowly, in orienting to a known goal—its home, and in homing successfully and repeatedly by passing through territory unknown to it. The cat's known goal, it should be remembered, is not a point but a region, which if irregular, may be quite extensive; whatever the form of this familiar area might be, a cat would be as much at home upon any part of it as when on the hearth of its master's house. The bird, which orients to a region of far greater size, could be expected to have the power of returning to it from a correspondingly greater distance; and if there is a distinction between proximate and distant orientation there must be a division of territory surrounding the goal or its center based upon the presence or absence of familiar landmarks of some sort.

Wallace[7] maintained that the cat was able to return to its home by the aid of its olfactory sense, that is by picking up in reverse order, link by link, a chain of different odors, which it had expe-

[6] Watson, J. B., and Lashley, K. S.: "Homing and Related Activities of Birds," Carnegie Institution of Washington, Publication No. 211, Washington, 1915.

[7] Wallace, Alfred Russel: "Inherited Feeling," *Nature*, vii, p. 303, London, 1873; also "Perception and Instinct in the Lower Animals," *ibid.*, p. 65.

rienced in its going out; in other words the cat smelled its way out and back, though leaving no tracks of its own. Aside from the assumption that the cat possesses an acute sense of smell, which is probably erroneous, not to speak of the necessarily mixed and transitory character of all odors in the air, we have seen that as a matter of fact the cat does not always return over the course by which it was taken out; on the contrary it often follows the shortest and most direct route. Darwin[8] thought that the power of returning to a region from which an animal had been deported, when indications were lacking, might imply the faculty of keeping a dead reckoning or of registering the various deviations or turns made in course of the journey; he declined, however, to discuss the question as his data were insufficient.

Since the animal does not always or usually return, as we have seen, over the original course, it is evident that it is not called upon either to exercise a prodigious memory or to repeat reflexly or otherwise the movements which such a supposed "backtracking" would imply.

We have shown that the cat can return at night, and think it probable that it homes mainly during the hours of darkness. In the greatest distances covered in these experiments (Nos. 4 and 1) or 3 and 4.6 miles, respectively, the animals had in one case 28½ hours and in the other 17 hours of night-time available; if they moved forward only or mainly after dark the first would have taken an average of nine hours to the mile, while the last would have cut this to four hours, which is rather good time for an animal which travels as slowly and cautiously as the cat.

When we are thus brought squarely before the problem of accounting for the return of this animal to its home region under the conditions described, we find no solid ground on which to tread; what follows must be regarded as mainly conjecture: (1) The animal seems to have a direction-constant with reference to its home-region, which it retains through the journey out, in spite of all the manifold turnings and twistings to which its body may be subjected; the animal will not have to recover what it does not lose; if this direction-constant is lost the animal will be lost; (2) This power of maintaining orientation does not depend upon memory nor, as already indicated, upon the receptors which mediate vision, hearing or smell; (3) We get over no difficulties by assuming, as has been often done, a "sense of direction," for direction to such an animal, it would seem, can mean only the spatial relation between its body and such objects as appeal to it; and out

[8] Darwin, Charles: "Origin of Certain Instincts," *ibid.*, p. 417.

of the total effective environment of the cat no objects probably make a stronger appeal than its home or the young which it may shelter; (4) Though of course possible, it is rather improbable that an animal like the cat possesses important unknown sense-organs which come to its aid in orientation; (5) By the process of exclusion we seem to be thrown back upon (a) mental imagery, or a relation established between the visual and the visualized fields, and (b) the kinesthetic sense, the sense of movement, or as it is sometimes called the "muscle sense," which is of sufficient delicacy to yield an impulse to action whenever the body is moved.

It may be too great a tax upon our credulity to believe that the cat can form and utilize mental images in such an effective way as do human beings, and especially since blindfolding does not appreciably affect the homing power. Accordingly I am inclined at present to believe, though unable to prove, that the secret of this power lies in the kinesthetic sense, which is older by far than either seeing, smelling or hearing, and by which compensatory movements of the body can be made and maintained; in other words that the constant sought lies back of the ordinary sense-organs, and that this is in some way bound up with this primitive muscle sense, which experiment has already shown to be of far greater delicacy in many animals than in man. It would seem that Hodge's cat, to which we referred, perceived every movement of the boat, and compensated for the movement when given its freedom; if the water in that lake had suddenly become dry land, is there any doubt that the animal would have made its home in short order, as our cats have repeatedly done, when removed a much greater distance from hearth and young, and when blindfolded at that?

Whether deviations in the position of the body are constantly adjusted by compensatory movements of some sort is a matter which future experiment must decide; it did not occur to me to keep the cats under close observation during their journeys out. It does not seem probable that such an animal is able to keep a register of its movements, if it were called upon to do so, in the way Darwin suggested; were this the case it would be a perfect homing machine.

FISHES: WHY STUDY THEM?

By ALBERT W. C. T. HERRE

THE PHILIPPINE BUREAU OF SCIENCE

WHY should any one study or want to study fish? Perhaps every man who is not a lounge lizard or a confirmed valetudinarian, certainly every boy, to say nothing of many girls and women, likes to escape from the trammels of every-day life and the suffocating indoor artificialities of cities and go a-fishing. Whether it is the outdoor freedom, the lure of stream or forest, mountains or the sea, or the joy of hauling in the big fellows, the fish or the fun of fishing, we must leave to each individual to determine. At any rate few despise the after period of rest and reminiscence, when crisp trout or flaky black bass, salmon bake or Spanish mackerel *aux fines herbes,* refresh and fortify against the next day's adventures.

But to spend most of the year swapping fish yarns and overhauling tackle and the rest of the time trying to catch fish is not studying fish, although the true "compleat Angler" does really and truly study fish.

The number of people who are interested in fish in one way or another is very great, in some countries including the total population, while in countries like the United States it is far greater than one realizes. Yet, like some other things of primary economic importance very few people really know anything about fish, and still fewer make a thorough study of them, though many people are vitally interested in some economic aspect of fishes.

From the earliest times man has undoubtedly eaten fish whenever he could get any, and with the spread of mankind many ingenious devices were invented for their capture, long before the dawn of any existing historical records. Since fish cost nothing to breed or maintain, and since in many regions they came periodically in uncountable numbers, many groups of people, especially in cold climates, came to depend upon them as their most important food. In other regions, such as the low coastal plains of Asia and the islands adjacent, fish became the most important source of protein food.

Although at first a purely utilitarian proposition, fishing, like hunting, with the advent of organized society came to be a recognized sport many thousands of years ago.

Very early in the historical period far-seeing men in regions like Egypt or China began to develop the artificial culture of fresh-water fish to supplement the food supply of a rapidly increasing population. In like manner the people of Java, the Philippines, Formosa and Hawaii developed systems of pond culture for certain marine fishes. Their methods are still in use and consist in catching the newly hatched fry in the rivers or sea and transferring them to ponds where they are kept till large enough for market, herbivorous fishes only being reared.

Before the dawn of history people had also learned to dry fish both with and without the use of salt, and to cure them by smoke. Later came such processes as pickling in brine, or with the use of vinegar or spices.

With the advent of Christianity into northern Europe and the subsequent change from savagery to civilization, fish and fisheries became increasingly important and many regions arose from nothing because of their control of the production or distribution of fish. We may trace the rise of modern Holland to her development of a special method of preparing herring.

As population increased and certain countries turned their attention more and more to foreign trade, valuable fishing grounds came to be in great demand, and regions like the Grand Banks were a matter for statesmen and diplomats and fleets to struggle over.

In primitive society only a small proportion of the total quantity of fish was taken and the balance of nature was never destroyed. As population increased the additional number of fish required was obtained by improvements in capturing and preserving, while the better organization of society ensured their distribution more evenly and to more remote regions. This greater and slowly increasing call for food continued for centuries without seriously impairing anywhere the sources of supply. It was not until the advent of the modern industrial period and its rapid development that the rivers of regions like England and the North Atlantic coast of our own country began to lose their importance as sources of food supply, and later still when the tremendous increase of factory industries destroyed the swarms of luscious fish which annually visited them.

But it remained for the enormous development of fish canning to practically destroy the annual run of Pacific coast salmon, an industry which rightly handled should have been as permanent as the production of wool or beef.

It is a bitter commentary upon the organization of modern industrialism that, as a rule, the men who are in business know

little or nothing about the thing which they are exploiting. The fish canner was compelled to know something about the processes of canning, often paying very dearly for his knowledge, and he knew more or less about how to sell the finished product, but as for knowing anything about fish—salmon, for instance—his ignorance was incredibly profound. As a result the salmon is, in some of the regions where it was almost unbelievably numerous, practically extinct because the packers not only were entirely ignorant but would not pay any attention to those who did know, and used their political influence to destroy the labor of those who would have made their industry a permanent one.

Another modern method of totally destroying the food supply upon which millions of people depended was exemplified in India, where the construction of dams for irrigation by well-meaning but ignorant politicians and engineers separated fish from their spawning grounds with fatal results. In other regions the taking of water for irrigation at a time when tiny young fishes swarm in the water, without providing in any way for their protection, has destroyed a primary source of food for the common people.

A little fundamental knowledge concerning fish and their life histories and habits would therefore certainly not come amiss to the business man, and would be of great utility to the far-seeing statesman or state executive, whether concerned with problems of food production and conservation, or taxation. Particularly should the latter have some slight modicum of knowledge in order to be able to appreciate the importance of fostering, to say nothing of improving, modern methods of fish culture which have revolutionized the fisheries of both fresh and salt water in many regions.

For a very long time there have been men who studied as best they could the fish life of their region, and since the time of Aristotle we have had more or less trustworthy written accounts of fishes. But the modern study of fishes dates from Artedi, a friend of Linnæus, and since that time a vast literature has arisen, treating of every conceivable topic which is in any possible way related to fishes, their lives, or any relation man sustains to them.

And yet with all this activity the actual number of people who are really engaged in studying fish is very small, and but few schools in the United States offer courses making fish the central or only subject of study. In spite of all that has been done and published, our ignorance of many problems of primary importance, zoologically and economically, is abyssal. For example, in the region in which I am now working, where fish form the principal animal diet of ten million people, we do not know the most elementary facts concerning a single fish in the Archipelago, in

spite of the fact that money spent in obtaining adequate knowledge of say the herring family would be repaid incredibly in advancing the economic and dietetic welfare of the people.

The surface of the world is by now pretty well explored, and there are no new continents or even very large areas of land or water to explore, outside of the polar regions. But enormous areas on a different plane remain to be explored and there is no question but what in time very considerable portions of the oceanic depths and bottom will be studied and the kind and relative abundance of their fishes well known. At the present time our knowledge of many regions is equivalent to that which would be gained by studying the fauna of a continent from samples gained by dragging a basket on a rope hanging from a balloon several miles up in the air. Large active fishes are not likely to be caught in a dredge and there may exist, in regions not too deep, vast numbers of fishes which some day will be known and utilized. Some of them may be known to-day from a few rare, strange examples, others are undoubtedly totally unknown as yet, but with improved methods of deep sea exploration and study man will learn their haunts and habits and be able to capture them in quantity.

Probably more young people become interested in zoology through their observations of birds or butterflies than in any other way, and it is not likely that anything will ever supersede them in beauty or attractiveness.

But a good exhibit of living fish attracts as many people as perhaps any other forms of life and in the tropics at any rate the coral reef fishes are only equalled in beauty and grace of form and color by the humming birds and butterflies. Fish are certainly attractive when living, and their study, whether of living or preserved specimens, can be made equally so if properly presented. It would seem, therefore, that more schools should offer courses where fish are the chief subject rather than merely dismissing them after the study of one or two types.

The zoologist and student of evolution should realize that no other group of vertebrates offers such enormous diversity of structure, form, habitat, habits and development as does that of the fishes, and then they should act on their knowledge.

The ignorance of even comparatively well-informed people about fish is stupendous. This is well illustrated when one tells a fish story. If he tells the plain unvarnished truth about climbing perch, the gobies or blennies that chase insects over the land and which leave the water for safety when you try to catch them, or even about plain ordinary Sangamon river catfish or Cumberland river eels, they put him down as a liar. But if by way of experi-

ment he really tells them something wholly imaginary they promptly accept it as fact and perfectly all right. Only the other day a party of tourists violently disputed what I was telling them about a fish in the Aquarium, although they had to admit they did not know anything about it. The trouble is that people have a preconceived idea of "fish," and of its limitations, and do not realize the enormous plasticity of the class of fishes. In the matter of fish shapes alone, no human being, even if gifted with the imagination of an insane Doré, could conceive the vast number of weird, grotesque, or "impossible" shapes which are actually found among living fishes. If we merely named examples, whether of unusual shape, strange physiological powers as that of electricity, almost unbelievable migrations as that of the common eel, startling metamorphoses, or astonishing habits, it would require a volume.

It is true that the study of systematic ichthyology requires the use of a large, expensive and bulky collection of alcoholic specimens, and access to an exceedingly diverse and often very expensive literature, but this last item is true of all systematic work, whether botanical or zoological. But the extended study of systematic ichthyology is only one phase, and by no means always the most important one at that, of the study of fishes. The collecting of fishes in a neighborhood or limited region is not difficult or expensive and their determination is a simple matter in Europe, North America, and many other regions. But there is a vast deal to study and to learn concerning the fishes of almost every region. Not only do many fishes undergo startling transformations, but the embryology and metamorphosis of many common fishes are totally unknown. In other cases "we only know a little and that is all wrong," as has been said about another matter. The breeding habits of many fishes, both salt and fresh water, are not at all known while their study could be carried on by any one willing to devote some time to it over a series of years.

The rate of growth, the time required to reach the reproductive period, the size reached and the duration of life after sexual maturity, are all problems concerning which we are ignorant even about many very common fishes, while their solution demands only careful observation over a term of years until sufficient data are accumulated to deduce the general principles underlying them. The migrations and seasonal movements of fishes, whether due to variations in the food supply, to sexual impulses, or to climatic causes, whether latitudinal or vertical in their range, are also matters of vital importance concerning which we have yet very much to learn.

Like all other organisms, fishes are the victims of disease,

"plague, pestilence and famine," while "battle, murder and sudden death" are of course their daily lot. Parasitic fungi, protozoa, crustacea and worms make life a burden to great numbers, and some of these, as certain tapeworms, may be readily transmitted to man. Yet very little is known of fish diseases and a vast amount of valuable work may be done without any necessity for a great collection of fishes. Many fish, often in uncountable numbers, are killed by some physiological disturbance which may be due to an incalculable increase in diatoms or flagellate protozoa, or to obscure causes which as yet we can not fathom. Proper conservation of the world's natural resources, therefore, asks that work be done along these lines, and in almost any college such research could be carried on while the results would benefit the whole nation.

Biology, any science, must find its excuse for existence in the extent to which it is capable of being interpreted or translated into terms of human welfare. Judged by this standard, the study of fishes, ichthyology, pisciculture, any of its departments is eminently worth while. The study of fishes, rightly considered and pursued, will in some one or more of its multifarious phases touch the life and affect the welfare of almost every one.

Whether it is the statesmen and scientists of Japan, nearly one third of whose redundant population derives its living from the fisheries, or Norway, striving to so husband and develop the fisheries as to permanently ensure food and a surplus for export, the professor studying the evolutionary aspects of degeneration or luminosity in fishes, or the business man who seeks the aid of ichthyologists in making his business of canning permanent by having it accord with the biological principles controlling the life history of the fishes he handles, all are alike profoundly interested in extending and perfecting our knowledge of fishes.

And is not the mountaineer with home-made tackle, or the city sportsman, or the Banks fisherman equally interested in the same thing? Yes, even though he does not always recognize or admit it. And it is the duty of the leaders of scientific education and thought to help to make him realize it.

And he, too, who gazes at fish with the eyes of artist or lover, enchanted by their marvelous variation of color and shape, and the grace and incredible speed of their movement, or it must be confessed sometimes amused by their grotesque or bizarre shapes or movements, is repaid in terms of human welfare.

Whether a human being be inspired by a poem, his emotions be transformed by the work of master musicians, or he is enraptured before a noble painting, he is certainly in contact with some-

thing which may profoundly affect human welfare, no matter how intangible or superfluous it may seem to some.

And so when one watches the incomparable beauty and grace of the living meteors that swarm about the coral reefs of the tropic seas and studies them in their environment, while the world of every-day affairs drops away from him, he is benefitted in the same way that a wonderful landscape, a perfect sunset or any work of art benefits the beholder.

We might add, too, that anything which helps to satisfy the thirst for knowledge concerning our world and all it contains is worth while, even if it served no other function.

By studying fish, we may be enabled to sustain or transform existing industries or develop new ones, thus adding enormously to the resources of society, we may throw additonal or even new light upon problems of development, animal distribution and evolution, and we may help to diffuse more generally interest in and knowledge of a group of animals second only to the domestic animals in importance and, taken in connection with their setting, unsurpassed in beauty and esthetic interest.

THE ETHER THEORIES OF ELECTRIFICATION

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IN a previous paper on "The Electric Fluid Theories" it was shown that neither the one fluid nor the two fluid theory gave any physical explanation of the cause of electric attraction or repulsion, though it was this explanation which was the principal purpose of the earlier emanation theory. It was also shown that a fundamental question which was left unsettled was how the electric fluid is held to a conductor while there is no attraction between it and the particles of matter.

The only theory proposed during this time which seems to suggest any explanation of this phenomenon was one proposed by Cavendish, who regarded the electric fluid in conductors as under an external pressure and as always flowing in the direction of least pressure. Cavendish did not discuss the question of the retention of a charge upon a conductor, for he regarded the electric fluid as being attracted by the particles of material bodies; but he seems to have had a very definite notion of an external pressure exerted upon the electric fluid in a charged body and of the reaction of the electric fluid to this pressure. Thus he says:

> When the electric fluid within any body is more compressed than in its natural state, I call that body positively electrified. When it is less compressed, I call the body negatively electrified.
>
> It is plain from what has been here said that if any number of conducting bodies be joined by conductors and one of these bodies be positively electrified, that all the others must be so too.
>
> If two bodies, both perfectly insulated, so that no electricity can escape from them, be positively electrified and then brought near each other, as they are both overcharged they will each, by the action of the other upon it, be rendered less capable of containing electricity; therefore, as no electricity can escape from them, the fluid in them will be more compressed, just as air included within a bottle will become more compressed either by heating the air or by squeezing the bottle into less compass: but it is evident that the bodies will remain just as much overcharged as before.

It will be seen from the above quotations that Cavendish regarded the compressed electric fluid in one charged body as capable of transmitting in some way a pressure to the fluid in another body brought near it. This would seem to indicate that he supposed

this pressure to be exerted by some external elastic medium which was itself thrown into a state of stress by the reaction of the compressed electric fluid.

Apparently the first physicist to definitely suggest the pressure of an elastic medium as the cause of electric attractions and repulsions was Dr. Thomas Young. In his lectures which were given before the Royal Institution and published in 1807 he says:

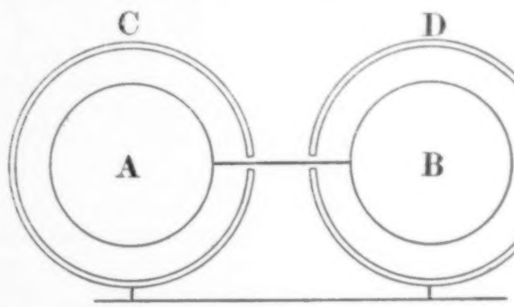
> It must be confessed that the whole science of electricity is yet in a very imperfect state. We know little or nothing of the intimate nature of the substances and actions concerned in it: and we can never foresee, without previous experiment, where or how it will be excited. We are wholly ignorant of the constitution of bodies, by which they become possessed of different conducting powers; and we have only been able to draw some general conclusions respecting the disposition and equilibrium of the supposed electric fluid from the laws of the attractions and repulsions that it appears to exert. There seems to be some reason to suspect from the phenomena of cohesion and repulsion that the pressure of an elastic medium is concerned in the origin of these forces; and if such a medium really exists, it is perhaps nearly related to the electric fluid.

Between the time of Cavendish's writing and the publication of Young's lectures there had been great advancement in electrical knowledge and very important improvement in facilities for electrical measurement. The most important discovery in electrostatics was Bennett's discovery of contact electrical charges. Galvani's discovery of muscular contractions due to electrical stimulation of the nerves had attracted a great deal of attention, and there was much controversy over the question whether the force with which Galvani was experimenting was really electrical, or whether it was some force before unknown and which was called Galvanism. This question was finally settled by Volta, who in 1796 discovered the electrical current set up in a circuit containing two metals and an electrolytic conductor. Then in 1800 Volta announced the discovery of the voltaic pile, by means of which the electromotive force of a single metallic pair could be increased to any desired degree. This was followed the same year by the discovery by Carlisle and Nicholson of the separation of water by electrolysis and very rapidly thereafter by the experiments of Davy and others on electrolytic dissociation. As a result of these investigations, the study of electrostatic phenomena was neglected, and aside from the work of Faraday but little of consequence has since been done in this field.

Faraday's most important contributions to electrostatics were his proofs of the perfect equality of the inducing and induced charges in all cases; his proof that electric induction might sometimes act in curved lines (as he stated it) and hence could not be

due to the action of forces at a distance, as such action would necessarily be rectilinear; and finally, in 1837, the discovery of specific inductive capacity.

This discovery as made by Faraday consisted in determining the division of an electric charge between two equal conductors when one was surrounded by air and the other by some other insulating medium. The apparatus used consisted of two brass balls 2.33 inches in diameter and exactly alike mounted upon insulating supports concentrically inside of two similar hollow brass spheres 3.57 inches internal diameter. The inner balls were carefully insulated from the outer hollow conductors, and the space between could be left filled with air or could be filled with some insulating solid or liquid. The outer hollow spheres were joined to earth.



Thus in the diagram in Figure 1 the inner spheres are indicated by A and B, the outer hollow spheres by C and D. C and D are joined to earth. If, now, A and B are connected and charged, then separated and the hollow spheres removed from around them, they are found to have equal charges.

Faraday found that when the space between A and C was half filled with sulphur and A and B were connected and charged as before and the outer spheres and the sulphur were removed A was found to have 2.24 times as great a charge as B. The experiment was repeated with glass, shellac and other substances instead of sulphur, and it was found that in every case A took a greater charge than B, but that the magnitude of the charge depended upon the insulating material between A and C.

Faraday believed that the so-called charges upon A and B were merely manifestations of some condition known as induction which had been produced in the medium between the inner and outer spheres, though why this condition should persist after the medium was removed he does not say. In Article 1174 of *Experimental Researches* he says:

The conclusion I have come to is that non-conductors, as well as conductors, have never yet had an absolute and independent charge of one electricity communicated to them, and that to all appearance such state of matter is impossible.

Again (Arts. 1177 and 1178), as far as experiment has proceeded, it appears, therefore, impossible either to evolve or make disappear one electric force without equal and corresponding change in the other. It is also equally impossible experimentally to charge a portion of matter with one electric force independently of the other. Charge always implies *induction,* for it can in no instance be effected without; and also the presence of the *two* forms of power, equally at the moment of development and afterwards. There is no *absolute* charge of matter with one fluid; no latency of a single electricity. This, though a negative result, is an exceedingly important one, being probably the consequence of a natural impossibility, which will become clear to us when we understand the true condition and theory of the electric power.

The preceding considerations already point to the following conclusions: bodies cannot be charged absolutely, but only relatively, and by a principle which is the same with that of *induction.* All *charge* is sustained by induction. All phenomena of *intensity* include the principle of induction. All *excitation* is dependent on or directly related to induction. All *currents* involve previous intensity and therefore previous induction. INDUCTION appears to be the essential function both in the first development and the consequent phenomena of electricity.

From this point of view, the charges of A and B in the above experiment were merely manifestations of some condition in the medium between A and C and between B and D. If A assumed a larger proportion of the total electrification than B, it was because induction took place more freely between A and C than between B and D. Faraday accordingly said that sulphur had a greater capacity for electrical induction than air, and that if the inductive capacity of air were taken as 1, the inductive capacity of sulphur would be greater than 2.24.

It may be interesting at this point to consider briefly the difference between the views of Cavendish and Faraday. Cavendish believed all bodies to contain an unknown quantity of a single electric fluid, and that this fluid was always under some kind of external pressure and that in conductors it always flowed toward the region of least external pressure and could be in equilibrium only when the external pressure was everywhere the same over the surface of the conductor or system of conductors in which the fluid was confined. From his point of view, the reason that A took a greater charge than B in the Faraday experiment was that the external pressure on a given charge was less around A than around B, and hence that an excess of fluid would flow into A until this external pressure was equalized upon the fluid in the two spheres.

Faraday attributed the state known as electrification not to any changed condition inside the charged conductor, but wholly to

conditions in the insulating medium surrounding the conductors concerned. A charged conductor was only one limiting boundary of an electrical field. A charge could not penetrate into a conductor, because the state of strain which was the essential condition of induction could not exist in conductors. In order for this state of strain to exist the bounding surfaces of the strained medium must be on different conductors insulated from each other, because from this theory the different surfaces must support equal and opposite stresses, and this is impossible over a conducting surface, which from its nature cannot support an electric stress at all. If the two surfaces of the region of strain, which Faraday called the dielectric, are joined by a conductor, the strain is relieved and the electrification disappears. Hence there can be no electrification upon the inner walls of a closed hollow conductor, since this would involve a condition of equal and opposite strains resting upon the same conducting surface.

It will be seen from the above that Faraday's theory does not involve the existence of any electric fluid whatever. Faraday calls attention to this in a foot-note to his Article 1298. He says:

> The theory of induction which I am stating does not pretend to decide whether electricity is a fluid or fluids, or a mere power or condition of recognized matter.

Even in the production of a current Faraday does not admit the necessity for the passage of any electric fluid through the conductor. From his point of view, since charging a body consists in setting up a certain condition of strain in the dielectric between it and another body, or other bodies, so discharging an electrified body consists merely in removing this state of strain in the dielectric around it. This strain can exist permanently in an insulator; it breaks down rapidly in a conductor. While it is breaking down the current is said to be passing through the conductor.

Faraday's notion as to the nature of the condition which he called induction was not clear, as may be shown by the following quotation from Article 1298:

> Induction seems to consist in a certain polarized state of the particles, into which they are thrown by the electrified body sustaining the action, the particles assuming positive or negative points or parts, which are symmetrically arranged with reference to each other and the inducting surfaces or particles. The state must be a forced one, for it is originated and sustained only by force, and sinks to the normal or quiescent state when the force is removed. It can be *continued* only in insulators by the same portion of electricity, because they only can retain this state of the particles.
>
> . . . .
>
> When a Leyden jar is *charged*, the particles of the glass are forced into this polarized and constrained condition by the electricity of the charging

apparatus. *Discharge* is the return of these particles to their natural state of tension, whenever the two electric forces are allowed to be disposed of in some other direction.

The question as to the cause of this state of polarization is left entirely unanswered by Faraday, and this question is fundamental. The fact that electrical induction could take place in the best air pump vacuum seemed to require that all space must be filled with a medium made of polarizable particles, and this assumption was not readily accepted, especially at a time when the notion of force acting at a distance had become the common heritage of physicists. For this and other reasons Faraday's electrical theory did not meet with general acceptance at the time when it was proposed.

In 1873 Maxwell published the first edition of his *Electricity and Magnetism* which brought the fundamental ideas of Faraday into a position of prominence in English speaking countries which they have largely maintained up to very recent times.

Maxwell undertook to show in his treatise that the quantitative laws of electricity and magnetism which had been put into mathematical form on the assumption of forces acting at a distance could also be put into mathematical form on the basis of Faraday's notion of induction.

Thus Maxwell says:

I was aware that there was supposed to be a difference between Faraday's way of conceiving phenomena and that of the mathematicians, so that neither he nor they were satisfied with each other's language. I had also the conviction that this discrepancy did not arise from either party being wrong.

I was first convinced of this by Sir William Thomson, to whose advice and assistance, as well as to his published papers, I owe most of what I have learned on the subject.

As I proceeded with the study of Faraday, I perceived that his method of conceiving the phenomena was also a mathematical one, though not exhibited in the form of mathematical symbols. I also found that these methods were capable of being expressed in the ordinary mathematical forms, and thus compared with those of the professed mathematicians.

For instance, Faraday, in his mind's eye, saw lines of force traversing all space where the mathematicians saw centers of force attracting at a distance: Faraday sought the seat of the phenomena in real actions going on in the medium; they were satisfied that they had found it in a power of action at a distance impressed on the electrical fluids.

When I had translated what I conceived to be Faraday's ideas into a mathematical form, I found that in general the two methods coincided, so that the same phenomena were accounted for, and the same laws of action deduced by both methods, but that Faraday's methods resembled those in which we begin with the whole and arrive at the parts by analysis, while the ordinary mathematical methods were founded on the principle of beginning with the parts and building up the whole by synthesis.

I also found that several of the most fertile methods of research discov-

ered by the mathematicians could be expressed much better in terms of ideas derived from Faraday than in their original form.

Maxwell takes pains to emphasize this statement of the purpose of his treatise. Thus in Vol. II, p. 176, 3d Ed., he says:

> It was perhaps for the advantage of science that Faraday, though thoroughly conscious of the fundamental forms of space, time and force, was not a professed mathematician. He was not tempted to enter into the many interesting researches in pure mathematics which his discoveries would have suggested if they had been exhibited in a mathematical form, and he did not feel called upon either to force his results into a shape acceptable to the mathematical taste of the time, or to express them in a form which mathematicians might attack. He was thus left at leisure to do his proper work, to coordinate his ideas with his facts, and to express them in natural, untechnical language.
>
> It is mainly with the hope of making these ideas the basis of a mathematical method that I have undertaken this treatise.

Maxwell accordingly undertook to specify the conditions in a dielectric medium by means of which the induction effects discussed by Faraday could be explained from the known laws of mechanics. In doing this he used as much as possible the fundamental concepts of Faraday in so far as these could be determined.

Faraday's researches were carried on through a term of years and were presented as they were finished. Naturally, one who departed so fundamentally in his electrical concepts from all who had preceded him, and who discovered so many new phenomena in electricity and magnetism, was obliged to modify his views as he proceeded. In his *Experimental Researches* Faraday gives us, not his mature opinion at the conclusion of his work, but the evolution of his theory as it took shape in his mind. It is accordingly possible to get different notions of Faraday's theory from different parts of his Researches.

Thus, in the discussion of induction which has been in part quoted Faraday speaks of the phenomena as being entirely due to a condition in the dielectric medium, and he discusses the direction of the lines of force of the inductive stress in this medium. In the early stages of his work he uses the term "lines of force" in a purely mathematical sense, that is, as giving throughout their length the *direction* of the inductive force. Later he came to think of the dielectric medium as consisting wholly of *physical* lines of force. In one of his latest papers (Proc. Roy. Inst., June 11, 1852) he discusses the characteristics which must distinguish physical lines of force from abstract, or mathematical, lines of force, and decides that both electrical and magnetic phenomena are dependent upon physical lines of force; that is, the lines of force are no longer used to *describe* phenomena, but to *explain* them.

His later ideas as to the nature of these physical lines of force are perhaps most fully explained in a letter to Richard Phillips, Esq., written in May, 1846, and published in *Experimental Researches,* III., p. 447. Some extracts from this letter are given below.

> You are aware of the speculation which I sometime since uttered respecting that view of the nature of matter which considers its ultimate atoms as centers of force, and not as so many little bodies surrounded by forces, the bodies being considered in the abstract as independent of the forces and capable of existing without them. In the latter view, these little particles have a definite form and a certain limited size; in the former view such is not the case, for that which represents size may be considered as extending to any distance to which the lines of force of the particles extend: the particle indeed is supposed to exist only by these forces, and where they are it is. The consideration of matter under this view gradually led me to look at the lines of force as being perhaps the seat of the vibrations of radiant phenomena.
>
> . . . .
>
> The ether is assumed as pervading all bodies as well as space: In the view now set forth, it is the forces of the atomic centres which pervade (and make) all bodies, and also penetrate all space. As regards space, the difference is, that the ether presents successive parts or centres of action, and the present supposition only lines of action; as regards matter, the difference is, that the ether lies between the particles and so carries on the vibrations, whilst as respects the supposition, it is by the lines of force between the centres of the particles that the vibration is continued.

Again, in *Experimental Researches* II, p. 291, Faraday presents his theory of the nature of matter in much the same manner as above. At the conclusion of this discussion, he says:

> The view now stated of the constitution of matter would seem to involve necessarily the conclusion that matter fills all space, or, at least, all space to which gravitation extends (including the sun and its system); for gravitation is a property of matter dependent on a certain force, and it is this force which constitutes the matter. In that view, matter is not merely mutually penetrable, but each atom extends, so to say, throughout the whole of the solar system, yet always retaining its own centre of force.

We see from the above that Faraday's later electrical theory was based upon a concept of the nature of matter which is no longer regarded as tenable, but which necessarily profoundly modified his views on electrical phenomena. It did away at once with all distinction between matter and the ether, unless those parts of space in which the centers of force were less numerous than in other parts could be regarded as a separate medium. Any question as to the number of electrical fluids, or whether there was any electrical fluid at all, could have little significance. The atoms of bodies were merely centers from which innumerable contractile filaments which he called lines of force radiated in all directions and throughout all space. From his reasoning, these filaments

must extend to the limits of the physical universe, and every point in space must be traversed by lines from all the centers in the universe, as otherwise there would be points in which the law of gravitation would not apply. Whether these lines of force are of different kinds, so that gravitation depends upon one kind, electric phenomena upon another kind and magnetic phenomena upon a third kind, Faraday does not state, but this condition would seem to follow from the rest of his theory.

When Maxwell undertook to interpret Faraday to the mathematicians he was compelled to choose between the more or less contradictory views which Faraday had expressed at different times, and he naturally undertook to select the views which could be used as the most satisfactory basis for a mathematical theory of electricity and magnetism. In doing this, he does not adopt Faraday's extreme views of the identity of matter and force. The distinction between force and energy was much more clearly understood at the time of Maxwell's writing than it was when Faraday was carrying on his investigations. In fact, energy, as a concept distinct from force, was not known to Faraday, and Maxwell shows early in his treatise that what had been defined as electricity or electrical quantity could not be measured as energy. He does, however, adopt Faraday's concept of physical lines of force, but somewhat in the manner of Faraday's earlier views, in which the lines of force were regarded as chains of polarized material particles.

Maxwell first defines his lines of force in a purely mathematical sense. Thus he says (*Elec. and Mag.* I, 97):

> If a line be drawn whose direction at every point of its course coincides with that of the resultant intensity at that point, the line is called a Line of Force.
>
> In every part of the course of a line of force, it is proceeding from a place of higher potential to a place of lower potential.
>
> Hence a line of force cannot return into itself, but must have a beginning and an end. The beginning of a line of force must, by Number 80, be in a positively charged surface, and the end of a line of force must be in a negatively charged surface.

It is easily seen that such a line of force does not pull the positively and negatively charged surfaces together. It is merely the path along which a positively or negatively electrified particle would move if set free on the line of force. It does not explain the motion of the particle, it merely describes it. When he undertakes to explain *why* an electrified particle would travel along a line of force, Maxwell says:

> At every point of the medium there is a state of stress such that there is a tension along the lines of force and pressure in all directions at right

angles to these lines, the numerical magnitude of the pressure being equal to that of the tension, and both varying as the square of the resultant force at the point.

In another place Maxwell argues that the state of stress described above is the only one consistent with the observed mechanical action of the electrified bodies and also with the observed equilibrium of the fluid dielectric which surrounds them.

Sir J. J. Thomson, who edited the third edition of Maxwell's treatise, takes exception to this claim. He says in a foot-note on page 165:

> The subject of the stress in the medium will be further considered in the supplementary volume; it may however be noticed here that the problem of finding a system of stresses which will produce the same forces as those existing in the electric field is one which has an infinite number of solutions. That adopted by Maxwell is one which could not in general be produced by strains in an elastic solid.

This, in connection with the preceding quotation from Maxwell, indicates that Maxwell regarded his dielectric medium as necessarily a fluid; hence when the only dielectric between the positive and negative electrical condition is the ether of space, this medium must be a fluid. This seems to contradict the well-known fact that the only known forms of ether radiation are of the nature of transverse waves.

Maxwell goes no further than Faraday in explaining the condition of stress which is supposed to constitute induction. He merely attempts to describe it. He says:

> It must be carefully borne in mind that we have made only one step in the theory of the action of the medium. We have supposed it to be in a state of stress, but we have not in any way accounted for this stress, or explained how it is maintained.
>
> . . . .
>
> I have not been able to make the next step, namely, to account by mechanical considerations for these stresses in the dielectric. I therefore leave the theory at this point, merely stating what are the other parts of the phenomenon of induction in dielectrics.

Maxwell's claim is, accordingly, that if the dielectric medium between two charges, said charges being always necessarily upon the opposite surfaces of the dielectric, should contract in the direction of the lines of force normal to its charged boundaries and should expand in all directions at right angles to these lines of force, this contraction and expansion would enable him to account for the other phenomena of electrostatic induction.

Maxwell does make the further assumption that this stress in the dielectric is analogous to an elastic stress in material bodies. Thus he says:

The analogy between the action of electromotive intensity in producing electric displacement and of ordinary mechanical force in producing the displacement of an elastic body is so obvious that I have ventured to call the ratio of the electromotive intensity to the corresponding electric displacement the *coefficient of electric elasticity* of the medium. The coefficient is different in different media, and varies inversely as the specific inductive capacity of each medium.

Farther along in his treatise Maxwell argues that this "Electric Elasticity" is the elasticity by means of which light waves are propagated through the ether. Thus he says (Vol. II, p 431):

According to the theory of emission, the transmission of energy is effected by the actual transference of light corpuscles from the luminous to the illuminated body, carrying with them their kinetic energy, together with any other kind of energy of which they may be the receptacles.

According to the theory of undulation, there is a material medium which fills the space between the bodies, and it is by the action of contiguous parts of this medium that the energy is passed on from one portion to the next, till it reaches the illuminated body.

The luminiferous medium is therefore, during the passage of light through it, a receptacle of energy.

In the undulatory theory as developed by Huyghens, Fresnel, Young, Green, etc., this energy is supposed to be partly potential and partly kinetic. The potential energy is supposed to be due to the distortion of the elementary portions of the medium. We must therefore regard the medium as elastic. The kinetic energy is supposed to be due to the vibratory motion of the medium. We must therefore regard the medium as having a finite density.

In the theory of electricity and magnetism adopted in this treatise, two forms of energy are recognized, the electrostatic and the electrokinetic (see Arts. 630 and 636), and these are supposed to have their seat, not merely in the electrified or magnetized bodies, but in every part of the surrounding space, where electric or magnetic force is observed to act. Hence our theory agrees with the undulatory theory in assuming the existence of a medium which is capable of becoming the receptacle of two forms of energy.

Let us next determine the conditions of the propagation of an electromagnetic disturbance through a uniform medium, which we shall suppose to be at rest, that is, to have no motion except that which may be involved in electromagnetic disturbances.

Maxwell then proceeds to develop an equation for the velocity of an electromagnetic disturbance in terms of the specific inductive capacity and the magnetic permeability of the medium and which, if the specific inductive capacity be taken as the reciprocal of the elasticity and the magnetic permeability be taken as the density of the medium gives an expression for the velocity of a wave motion in an elastic medium. It also gives an expression for the ratio of the electromagnetic to the electrostatic unit of electricity, or the velocity with which a unit electrostatic charge must move in order to become electromagnetically a unit current. This ratio can be determined experimentally, and gives a quantity numerically equal to the velocity of light.

He then says:

In other media than air the velocity V is inversely proportional to the product of the dielectric and the magnetic inductive capacities. According to the undulatory theory, the velocity of light in different media is inversely proportional to their indices of refraction.

There are no transparent media for which the magnetic capacity differs from that of air more than by a very small fraction. Hence the principal part of the difference between these media must depend upon their dielectric capacity. According to our theory, therefore, the dielectric capacity of a transparent medium should be equal to the square of its index of refraction.

In Maxwell's theory we accordingly find the dielectric medium of Faraday identified with the luminiferous ether. But the elasticity of the luminiferous ether which is involved in the transmission of all known forms of radiation must be of the nature of rigidity, and a fluid dielectric such as Maxwell's assumption of contracting lines of force seems to require does not possess rigidity.

It would accordingly seem that while Maxwell's method of calculating the velocity of light from purely electrical experiments *seems to prove beyond question that the luminiferous ether is the medium of electric and magnetic induction*, the assumption as to the contraction of this medium in the direction of the electrical lines of force and its expansion in all directions at right angles to these lines may require modification.

It is plain that this assumption that an electrical charge is merely one aspect of a stress in the ether is equivalent to a denial of an electrical substance *per se*. It is difficult to see, however, how from the assumption of a mere contraction of the dielectric between two conductors the surfaces of the conductors could be put in qualitatively different electrical conditions such as are known to distinguish positively and negatively electrified bodies. Both aspects of such a stress would appear to be exactly alike, just as the stresses at the opposite ends of a stretched elastic cord.

It accordingly became necessary to make some further assumptions to account for the difference in the positive and negative electrical surfaces. Here recourse was again had to Faraday's notion of a polarizable medium; that is, a medium made up of particles having opposite electrical properties at two opposite extremities. The ether accordingly came to be regarded by many of Maxwell's successors as made up of particles or "cells" holding positive charges on one side and negative charges on the opposite side, very much as the current magnetic theory regards a magnet as made up of molecules having a north magnetic pole on one face and a south magnetic pole on the opposite face. The polarization of the medium in electrical induction was supposed to consist in the orientation of these hypothetical particles so that their charges of the same kind were turned in the same direction.

Thus Lodge (*Modern Views of Electricity*, p. 349) says:

Is the ether electricity then? I do not say so, neither do I think that in that coarse statement lies the truth; but that they are connected there can be no doubt.

What I have to suggest is that positive and negative electricity together may make up the ether, or that the ether may be sheared by electromotive forces into positive and negative electricity. Transverse vibrations are carried on by shearing forces acting in matter which resists them, or which possesses rigidity. The bound ether inside a conductor has no rigidity; it cannot resist shear; such a body is opaque. Transparent bodies are those whose bound ether, when sheared, resists and springs back again; such bodies are dielectric.

A similar view to this was expressed in most text books on Electricity written in the English language between 1890 and 1900. Thus in his well-known text book on Electricity and Magnetism (Edition of 1895) S. P. Thompson attempts to define electricity as follows:

Electricity is the name given to an invisible agent known to us only by the effects which it produces and by various manifestations called electrical. These manifestations, at first obscure and even mysterious, are now well understood; though little is yet known of the precise nature of electricity itself. It is neither matter nor energy; yet it apparently can be associated or combined with matter; and energy can be spent in moving it. Indeed its great importance to mankind arises from the circumstance that by its means energy spent in generating electric forces in one part of a system can be made to appear as electric heat or light or work at some other part of the system; such transfer of energy taking place even to very great distances at an enormous speed. Electricity is apparently as indestructible as matter or energy. It can neither be created nor destroyed, but it can be transformed in its relations to matter and to energy, and it can be moved from one place to another. In many ways its behaviour resembles that of an incompressible liquid; in other ways that of a highly attenuated and weightless gas. It appears to exist distributed nearly uniformly throughout all space. Many persons (including the author) are disposed to consider it as identical with the luminiferous ether. If it be not the same thing, there is an intimate relation between the two. That this must be so is a necessary result of the great discovery of Maxwell—the greatest scientific discovery of the nineteenth century—that light itself is an electric phenomenon, and that the light waves are merely electric, or, as he puts it, electromagnetic waves.

In 1893 J. J. Thomson published his *Recent Researches in Electricity and Magnetism*, in which he carried the Faraday-Maxwell theory to a development almost as extreme as the later views of Faraday, to which reference has already been made. Only a short time later, he and his fellow workers succeeded in identifying the electrical fluid concerning whose existence there had been so much argument for 150 years. The development of the ether theory by Thomson should form the subject of another paper.

FALSIFICATIONS IN THE HISTORY OF EARLY CHEMISTRY

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THE earliest developments of any science present difficulty to historians by reason of the fragmentary character of surviving records, but with the progress of time and the advance of research the story becomes gradually clearer and more coherent. In the case of the history of the science of chemistry, however, more perhaps than in any other, factors have been operative that have made peculiarly difficult the solution of the problems of its early history.

The beginnings of the history of chemical theory, the notions of the nature of matter and its changes are found in the Greek philosophers from Thales to Aristotle, and for our knowledge of these we are mainly dependent on the records of Plato and Aristotle.

For our knowledge of the earliest data on the practical arts of chemistry we are in the first instance dependent upon evidence accumulated by archeological research with respect to remains of works of art or manufactures involving chemical knowledge or skill; in the second instance, to surviving documentary records of ancient times of established authenticity.

Such in the domain of chemistry are, particularly, Theophrastos of Eresus (born 371 B. C.), Pollio Vitruvius (1st century B. C.), Dioscrides and Pliny the Elder (first century A. D). These writers were, however, not chemists by occupation or by experience.

The earliest practitioners of the chemical arts of whom we have some definite knowledge appear to have been Egyptian or Greek-Egyptian practitioners of the arts of metal working, goldsmiths and dyers. These arts seem to have been long held as a monopoly by a certain cult of the Egyptian priesthood, and these arts had been guarded and kept secret, only imparted to initiates bound by solemn oaths not to reveal them to the uninitiated.

The first recognition of this chemical cult and the philosophy developed by it connects with the Greek-Egyptian schools at Alexandria early in the Christian Era. The art called by the early Alexandrian writers the sacred or the divine art became only

gradually more widely known through the destruction of the pagan temples and schools, and the scattering of their scholars, by the early Christians.

The earliest known designation of this Greek-Egyptian art which gave rise to our word chemistry is the Greek word chemeia and is first met with in the third century of our era in writings of a Christianized Alexandrian, Zosimus, who endeavors to explain the origin of the term by a fabulous myth. The term is also met with in the same century in the decree of the Emperor Diocletian against the practice of this art of chemeia and ordering the destruction of all works relating thereto. This decree was issued, it appears, on account of the belief that these chemists were able to make artificial gold and silver and that thereby the finances of the empire might be seriously disturbed.

With the abolition of the Alexandrian and other pagan schools and the downfall of the Egyptian priesthood, their chemical arts as practiced were indeed not lost, though their practitioners were scattered. The early scholars of this chemical cult did not write for the public. Those who in time ventured to write about the sacred art, either by reason of their desire not to be considered as violating their oaths of secrecy, or for fear of not being thought good Christians, wrote in obscure and mystical allegories or in vague descriptions of, or allusions to, processes which generally centered about the transmutations of base metals to precious metals, or the preparation of elixirs and the philosopher's stone. With the increase of power of the Christian Church there seems to have been a decline of interest in Western Europe in this phase of Alexandrian chemical philosophy, though in Byzantium there seems to have been a cult which kept alive to some extent those traditions and ideas and preserved such writings as then existed.

With the rise of the Moslem power and their conquests of Persia, Asia Minor, Egypt, Morocco and Spain in the sixth to the eighth centuries, the Arabs absorbed and assimilated the Greek Alexandrian science, which had been preserved and cultivated notably by Syrian schools founded by fugitive scholars from Alexandria and other suppressed pagan schools. This Greek science of chemeia thus became known as al-chemia, under which name it was in the eleventh to the thirteenth centuries again introduced to western Europe, largely through the medium of Christian scholars from Spain, Italy and other nations who studied at the Spanish Mohammedan schools.

This re-introduction into Europe of Arabian elaborations of Greek-Egyptian alchemy was not without serious opposition. It was very generally believed that the alchemists possessed the power

to make gold and silver from base metals, and hence their activities were viewed with suspicion by civil and ecclesiastical authorities who feared that state or national finances might be disturbed. Monarchs of France and of England and other lesser rulers, and in the fourteenth century Pope John XXII forbade under penalties the practice of alchemy and the possession of alchemical literature. As the practice of alchemy was often associated with supposed magical powers and the cooperation of evil spirits, church authorities, both Christian and Mohammedan, endeavored to suppress alchemists and their writings.

One natural result of this situation was to discourage conservative and law-abiding persons of scholarly taste from entering this field of science. Another result was to cause those who nevertheless refused to heed the prohibition decrees either to exercise great caution in their expressions or to conceal their identity as authors.

There were numerous such alchemical writers, for the administrative machinery was notoriously defective in those times and the hope of gain in wealth or long life of many influential and powerful persons—even princes—often operated to protect many who pretended to possess the great art.

Thus in the middle ages, while there were written a very large number of treatises on alchemical philosophy or pretending to the knowledge of transmutation or to give instruction in the art, such writings were nearly always anonymous or pseudonymous. The authors concealed their personal identity by issuing their manuscripts without name, place or date, by giving false dates and places, or to give their writing greater importance by ascribing them to some author of established authority in some natural science, safely dead.

During this period also the literature of technical chemistry outside of the domain of alchemy proper was very meager. The artisans and manufacturers were not generally scholars. They had also little object in informing the public generally as to the details of their business. So far as writings of that character were issued, they were for the use of a limited constituency and attracted little notice outside of the particular trade for which they had practical value. Such manuscripts were rarely preserved in permanent collections or libraries.

From these causes it can be understood that the history of chemistry in the middle ages presents peculiar difficulties, and that surviving records give occasion for many perversions of history. An early instance of such perversion is found in early writings issued under the name of Democritus and generally attributed to the Greek

philosopher Democritus of Abdera (5th Century B. C.). The writings in question, however, are typical alchemical of the Alexandrian school. While they contain recipes for making imitations of gold and silver, and for dyes and dyeing, etc., they contain also much mystical philosophy and obscure allegories. Even Pliny, about 75 A. D., refers to magical and superstitious writing of Democritus, and expresses the belief that they are by Democritus of Abdera, though he admits that that is disputed by others. Pliny's contemporary, Columella, however, asserts that much that is attributed to Democritus was in reality written by a certain Bolos of Mendes in Egypt. This psuedo-Democritus was held in the highest reverence by later alchemists and by them generally considered as Democritus of Abdera. Zosimus about the third century A. D. refers to him as a great master of the art. So late as the eighteenth century Lenglet du Fresnoy in his history of alchemy assumes that Democritus of Abdera is the author of this literature, though by later historians it is well recognized that the alchemist Democritus is a writer of between the first and third centuries of our era.

Even Aristotle was the victim of medieval impostors. Thus the work on minerals—*de mineralibus*—attributed to him seems to have been originally written by a Syrian-Arabian writer of about the ninth century, though rewritten and extended by later Latin editors. According to Ruska it is the earliest Arabian work on mineralogy and was a principal source of medieval mineralogy. Other works falsely attributed to Aristotle are not earlier than the 11th century and some much later.

So also the eminent Arabian physicians, Rhazes (Al Razi) of the 9th-10th centuries and Avicenna (Ibn Sina) of the 10th-11th centuries, were fraudulently credited with works of alchemical character of a century or so after their deaths, which were much quoted by Vincent of Beauvais, Albertus Magnus and Roger Bacon in the thirteenth century. These writing are now believed to have had no Arabian originals but to have been written by Latin writers in the 12th and 13th centuries.

A notable perversion of history was the appearance about 1300 A. D. of certain writings important in the history of chemistry purporting to be the work of the Arabian Geber, which was the Latinized name of Djaber. The real Djaber lived probably about the eighth century, and little is known of his personality. He is, however, considered by later Arabian alchemists as of high repute in the art. His writings seem to have been unknown to European chemists during the medieval period. Though his name appears two or three times among authorities of reputation, neither Vincent

of Beauvais nor Albertus Magnus seems to have known anything definite of his works. The works appearing under the name of Geber were very notable, and made a great impression in the fourteenth century. They were manifestly the work of an experienced and capable chemist familiar with and describing well methods of distillation, sublimation, many furnace operations and the preparation and purification of many metallic salts and solutions. They contained our first definite information concerning the preparation and use of mineral acids—sharp or corrosive "waters." The credulous middle ages accepted generally without question the authenticity of these works as by the eighth century Geber, and the early historians of chemistry, Hoefer, Gmelin, Kopp, accepted this interpretation. Kopp indeed in his "Geschichte der Chemie" expressed some doubts, but did not, however, alter the traditional course of history. In his later work, however—"Beiträge zur Geschichte der Chemische"—he gives strong reasons for doubting the early date of these writings and that they were indeed translations from any Arabian originals. It remained for M. Berthelot to establish beyond doubt the pseudonymous character of these writings. In the libraries of Europe he located and had translated a number of works, manuscripts in Arabic credited to the original Djaber or Geber. None of these works bore any resemblance in style or contents to the work of the Pseudo-Geber. They are indeed much more like the writings of the early Greek alchemical writings upon which they are manifestly based.

The acceptance of these thirteenth or fourteenth century writings as of Arabian origin in the eighth century up to very recent times has had the result of early Arabian chemists receiving credit for an advanced knowledge of chemistry which has not been evidenced by any Arabian literature known at the present time. This advanced knowledge is rather to be credited to some European chemists, probably both Mohammedans and Christians, of the latter part of the thirteenth century, and the Pseudo-Geber was probably not himself Arabian but a Latin-writing Spaniard or at any rate from some other country of southern Europe conversant with the development of Spanish-Arabian chemistry of that period.

The chemical literature of the fourteenth and fifteenth century contains almost nothing that evidences any material advance upon the Pseudo-Geber and his predecessors. Alchemical treatises of that period are indeed numerous. They are, however, nearly all anonymous, or pseudonymous. Many were ascribed to the authorship of prominent writers deceased. Many were ascribed to eminent churchmen—Albertus Magnus, St. Thomas Aquinas, Raimundus Lullus (Lully) and Roger Bacon. In the case of Albertus

Magnus, two alchemical papers attributed to him are included in the collection of his works published by the French government, though the principal one of these contains references to authorities long subsequent to his death. The judgment of recent students of chemical literature, on the basis both of internal and external evidence is that all alchemical literature attributed to Albertus, St. Thomas Aquinas and Lullus are the work of impostors of from a half-century to perhaps two centuries later. In the case of Roger Bacon, while there are genuine writings in which he talks about alchemy and expresses his faith in some of its claims, it appears quite certain that those writings which pretend to a personal experience in the alchemist's arts are all falsely attributed to him.

Raimundus Lullus was a prominent churchman and writer on theology and philosophy at the close of the thirteenth century who was killed at Tunis in 1315 while carrying on missionary work among the Moors. He was reputed as a great master of alchemy in the later middle ages, and a considerable alchemical literature exists under his name. His scholarly biographer, B. Haureau, cites the titles of some eighty alchemical treatises—printed or not—which are attributed to him, yet it seems well established that he wrote nothing of that kind. Several of the most popular and apparently earlier works are circumstantially dated between 1330 and 1333, and even these there are reasons to believe are antedated. The alchemical literature attributed to Lullus is probably not earlier than the middle of the fourteenth century and much of it later. It is also very probable that most if not all the alchemical treatises ascribed to the Spanish physician, Arnald of Villanova, another eminent authority with medieval alchemists, is apocryphal.

The early part of the sixteenth century is marked by three writers of note in the history of chemistry, Theophrastus von Hohenheim, called Paracelsus (1493-1541), Vannuccio Biringuccio (his single book on mining and metallurgy was published 1540) and George Bauer or Agricola (1494-1555). The well-known works of these authors were widely appreciated by their century, were printed and passed through many editions and translations. The works of Biringuccio and Agricola were both important technical treatises appealing mainly to mining and metallurgical coworkers. The works of Paracelsus were medical and chemical and dealt in his peculiar way with natural philosophy in general and attracted great attention on account of his emphasis upon the place of chemistry in medicine.

At the close of the sixteenth century and early in the seventeenth, there appeared certain treatises, printed in German, published by Johann Thölde, said by him to be translations of ancient

Latin manuscripts, and to have been written by an alleged Benedictine monk—Basilius Valentinus. The works attributed to Basilius attracted wide attention. They were a strange mixture of alchemical lucubration and of advanced chemical knowledge. They dealt with the importance of chemistry in medicine, and with chemical medicines. They criticized severely the medical profession. In all this they resembled the literature of Paracelsus. Moreover, the theory of the *tria prima*, of salt, sulphur and mercury as the constituent principles of all material substances, a theory which Paracelsus had formulated and much reiterated, was found just as clearly stated. Many passages were so similar in the writings of the two that students were not slow to infer that one author must have copied his ideas from the other. Much speculation and controversy was excited as to date and authorship of the Basilius literature, but eventually the seventeenth and eighteenth centuries accepted it as of the late fifteenth century and therefore pre-Paracelsan. To be sure, the archives of the Benedictine order when searched revealed the name of no such member, nor was any reference to any such author or his works known previous to 1600. Nor was any such specific chemical knowledge as was contained in some of these works contained in earlier writings than of the sixteenth century. No original manuscripts from which these books were supposed to be translated were ever in evidence.

As the bitter war in the medical profession between the opponents and partisans of Paracelsus and the chemical medicines introduced by him was then at its height, and the conservative and more scholarly university faculties and the conservative party in the medical profession were antagonistic to Paracelsus, it is not improbable that there was a willingness on their part to believe that Paracelsus had borrowed from Basilius rather than the contrary. However that may be, the result was that the Basilius literature was quite generally accepted as of the latter part of the fifteenth century, and the earlier historians, as Gmelin, Kopp and Hoefer and their successors, generally adopted this assumption. At the same time these historians were skeptical as to the existence of the alleged Dominican monk of that name.

Kopp, who in his history of chemistry (1843-7) had accepted the fifteenth century as the period of these writings, in his later "Beiträge zur Geschichte der Chemie" (1875) presented strong evidence that the Basilius literature was not previous but subsequent to Paracelsus, and in his last work "Die Alchemie" (1886) he reiterates his belief in the fraudulent character of the work and that Thölde himself was the real author, a conclusion which later

researches have only confirmed. Prof. Karl Sudhoff, than whom no living scholar is more conversant with the medical literature of that period, stated in 1913 in a personal communication that after perusing thousands of manuscripts there is no possible room for doubt but that the Basilius literature as well as the Hollandus literature is all post-Paracelsan.

The works attributed to the alleged father and son Hollandus are of the same period as those of Basilius. The date of the first treatise published under the name of Johann Isaac Hollandus is 1572, at which time practically all the Paracelsus literature had been printed. The rest of the Hollandus literature was considerably later. These works also contain much that is similar to much in Paracelsus. The doctrine of the three principles was here also clearly stated. These writings also professed to be of earlier date and were accepted by the seventeenth and eighteenth centuries as also of the fifteenth century on no definite evidence. The works of the two Hollandus, whoever they were, and if there really were two, are of much less interest or value than some of the Basilius works, yet they contained also a great many chemical facts or points of view not known to the fifteenth century, and the incorporation of this literature into the fifteenth century history in the systematic histories of Gmelin, Thomson, Kopp and Hoefer caused a perversion of the story of chemistry, and gave an importance to these writers which they would not have received if they had been located in their proper chronological order. Not only did the sixteenth century chemists not depend on them, but the authors of the Basilius and Hollandus literature had or might have had the advantage of the works of Paracelsus, Biringuccio, Agricola and other less important chemists of the sixteenth century.

Works of alchemical character were also published under the name of George Agricola entirely foreign to his thought and easily recognized as spurious by the historians of chemistry. The literature of Paracelsus still presents unsolved and difficult problems as to authenticity in the great volume of works attributed to him and first published thirty to forty years after his death.

The foregoing sketch makes no pretension to a complete account of falsifications in the early history of chemistry, but comprises the most notable instances and will serve to illustrate the difficulties that have attended the story of the early development of chemical science and the misapprehensions affecting the reputations of early scholars in science.

THE ORGANIZATION OF SCIENTIFIC MEN

By J. McKEEN CATTELL

THE modern world is notable for the advance of science, of education, of democracy and of social organization. It may be assumed by a scientific man in a scientific journal that the advance of science is the most fundamental, for it has made the others possible. The entire development of our industrial civilization is due to the applications of science. Democracy has progressed because the productivity of labor has been so multiplied that one man can now do the work that once required four, because the length of life has been so increased that the years of work are doubled. Available wealth having increased four-fold, education and equality of opportunity for all have become practical ideals.

Trade guilds, of which universities were once examples, date to long passed centuries; the modern period has witnessed an elaborate organization of industrial and social groups. Legislatures are themselves such groups, representing mainly the holding classes. In order to obtain legislation for others, such as woman suffrage or the improvement of the conditions of labor, special organization is required. It is equally essential in commerce and in industry. Corporations and trade unions have largely replaced the competitive system among individuals and are integral parts of our social order. There is scarcely any group that has been so backward in democratic organization as men of science; there is no other in which the conditions make the right kind of organization more necessary.

In the slow movement toward democracy men of science have played a curious part. Their work has made democracy possible, although this is a result that as a group they have neither sought nor recognized. They have indeed often regarded it as ignoble to do useful or profitable work and have not accepted as equals those who did such work. Men of science have come from the privileged classes or have been dependent on them. They do not earn their livings by scientific research, but are usually amateurs, having either inherited wealth or doing other work for the support of their families. The most typical scientific man to-day is a university professor, meagerly supported by charity to tutor the children of the well-to-do, devoting his spare time to science from curiosity and emulation.

The satisfaction of curiosity is a fundamental instinct, the game of scientific discovery is one of the finest of sports, the appreciation or kindly envy of others is a pleasant tribute; but the rewards of science are queerly out of proportion to what science has accomplished for human welfare. Mr. Carnegie and Mr. Rockefeller may return some of the millions acquired through the applications of science; but science would be indefinitely richer if a cent were paid to it each time a match were struck or a pin used. Full payment would be three fourths of the wealth produced annually by the industrial nations. It might be admirable for scientific men to give what they can and to get only what they need, if they did so voluntarily; but they deserve about as much credit as the natives in an African protectorate. And they do not get what they need, for their fundamental want is to be in a position to advance science to the limit of their ability.

The two most important services to society are the bearing and rearing of children and scientific research. Their performance has been dependent on fundamental instincts which organized society has done more to thwart than to strengthen. It is essential for the welfare of all that these services shall be rendered. It seems unlikely that women will permanently accept the promise of bliss in heaven as a reward for pain on earth, or that scientific men will regard a title or a degree, a medal or membership in an academy, as fit payment for their work.

Competitive social organization enables a man to sell his services to those who will buy them; it makes no provision for services to society. When physicians limit the spread of disease by learning its causes they are not paid, but on the contrary lose the fees of patients. When lawyers avoid litigation, their reward is the lack of retainers. Should newspapers seek to prevent war they would limit their circulation. And so it is in all directions.

Art, like science of universal value, is in a better economic condition, for its products can be sold. Joy in work should be the right of every worker; it may be the greatest in the creative work of art and of science; but it does not give exemption from the ordinary needs of life; it can scarcely exist if the worker has not the means and the time to do his work in the best way. Printing and engraving, methods of automatically reproducing acting and music, are scientific inventions which have made art both democratic and self-supporting. It is also the case that the state pays for works of art for the use of all. The people and the state must learn to pay for the products of scientific research.

The situation for science is slowly improving, but through the working of economic forces, rather than through the efforts of

scientific men. Students in medical, engineering and scientific courses must be trained by professors competent in science, and the university recognizes the advancement of science and scholarship as one of its functions. Foundations are endowed expressly for scientific research. Commercial firms need chemists, physicists and biologists in their business, and patent laws make some kinds of research profitable. The government has learned that it pays to employ scientific men for practical results, and that in some directions new investigations must be made. It is recognized that research not obviously and immediately useful is necessary, although no satisfactory method has been devised to defray its cost.

Society, controlled by privilege and precedent, has been parasitic on inborn instincts and inbred sentiments for its scientific research. The instincts and sentiments are in large measure inherited from the feudal and aristocratic period and will gradually atrophy, for the reactions only occur in answer to adequate stimuli. A complete revolution is demanded by modern democracy. The promotion of science being for the benefit of all is a function of the state and of a world organization. If a group of nations may make the maximum military establishment of a given nation a hundred thousand soldiers, it can perform a more useful function by making the minimum scientific establishment a hundred thousand men engaged in research. A decent regard for the opinions of mankind should lead each nation to support one research institution of the same cost as each of its battleships. The benefits of scientific research are greatest for the nation conducting it; but they accrue to the whole world, and each nation should contribute in proportion to its consumption.

Applied science has accomplished much by providing food, clothing and shelter for nearly all, bath-tubs, telephones and automobiles for many. But so long as

A man's work lasts from sun to sun,
A woman's work is never done,

so long as children work to their hurt and are denied the chance to prove what they can best do, the production of wealth must be further increased by scientific research and invention. By medicine, hygiene and better living conditions, infant mortality in some places has been reduced from one half to one tenth; cholera, smallpox, yellow fever and the plague have in large measure, tuberculosis, typhoid and other diseases have to some extent been controlled. But so long as ten million children die needlessly every year, so long as an epidemic of influenza may kill five million people, the need for research and its applications is more urgent than any other need.

Science has concerned itself mainly with the control of the physical world: the science of human conduct and of its control is only beginning. We have been more successful in the production of wealth than in its distribution and use. Our churches, schools, law courts, governments and other institutions are in large measure survivals from a pre-scientific and a pre-democratic era. But little has been done to investigate the relation of the individual to his surroundings and to make the most desirable adjustment, still less to obtain the best kind of individuals. The contribution of the psychological sciences to the production of wealth should equal that of the material sciences; their total contribution to human welfare should be greater. For science has not only supplied the economic basis for our civilization; it has not only made economic slavery wanton and intolerable; it has freed us from superstition and unreason; it is in itself the most perfect art and the best religion, the force not ourselves that makes for truth and righteousness.

"The harvest truly is plenteous, but the laborers are few." And this is in large measure because we limit ourselves to the solution of St. Matthew: "Pray ye therefore the Lord of the harvest, that he will send forth laborers into his harvest." We scientific men like "the conies are but a feeble folk"; but unlike them we do not make our "houses in the rocks"; rather as sheep we follow the shepherd to the shearing. We work for the lords of the harvest and depend on them to care for us. We have not awakened from the old dreams; we do not see the new world in which the workers of the world are learning to direct its work. What was printed many years ago is surely forgotten, so a reference[1] to the situation may be quoted as the writer saw it then, as he sees it now:

> Evolution has progressed by the survival of the strong and the cunning, of those armed with tooth and claw, of those quick to run and ready to hide. It has given us the vulture and the parasite. Human history has left us the legacy of the iron hand and the crooked back. The man engaged in scientific work has too often filled the position of an upper servant—a tutor to the sons of the rich, a priest subscribing to tenets that are outworn, an employee dependent on the favor of presidents and boards,—for whom silence is silver and flattery gold. As the downtrodden have submitted to servitude on the ground that they will have their reward in a future life, so scientific men have labored in the hope of recognition and posthumous fame. They have scrambled for degrees, titles, membership in academies and the like, trying to climb upon each others' necks. But the things that have been are not the things that shall be. The men who labor with their hands have learned to unite in trade unions; they have shown themselves ready and able to make the utmost sacrifices for their common cause. And they have won; they have used the governors of states and the president of the United States for their purposes. Their leader can speak to the president on terms of equality; the

[1] Address of the president of the American Society of Naturalists. *Science*, April 10, 1903.

members of the National Academy of Sciences waited last spring for an hour in the anteroom of the White House until he did them the honor to shake hands with them. Is there a university in the world whose faculty would resign because one member was unjustly treated, or would scientific men subscribe ten per cent. of their incomes to support a faculty that had so resigned? But the things that have been are not the things that shall always be.

Year after year has passed since this was written. The head of the American Federation of Labor still dictates to the president of the United States; scientific men still wait hat in hand on the almoners of Mr. Carnegie and Mr. Rockefeller. University professors even yet find silence to be silver, flattery to be gold. Now as then the National Academy of Sciences plays the part of an exclusive social club for those who have arrived. Royal Societies and Imperial Academies were fine embodiments of the spirit of a past period. The universities had fallen into dogmatic routine and external control; scientific men made notable progress by the organization of academies which they themselves conducted. Scientific invention was then youthful and vigorous; it was stimulating for the amateurs of a city to meet in a club to discuss their discoveries, usually trivial, but at times of fundamental importance.

But we no longer live in the seventeenth or the eighteenth century, even though their dead hands still lie heavy upon us. Science begot industrial civilization and must now dwell in the house of the giant that is its offspring. The noble and his serfs, the squire and his peasants, have been replaced by the capitalist and the proletariat. Kings yielded to parliaments, the barons to the commons. Now we have an unstable combination of indirect democracy and temporary dictators, while corporations and trade unions are becoming the real forces of government. The Bible has in large measure been supplanted by the newspapers, the church by the movies. Mr. Edison rather than Lord Rayleigh is the scientific representative of the industrial world. The park-like civilization of aristocracy with its hidden peasant hovels is being razed for the creation of cities and factories. The etiquette of the gentleman is yielding to the rough ways of democracy.

The adjustment of scientific men and their organizations to modern democracy has been slow and partial. The land that is the "mother of parliaments" was responsible for the organization of the first special scientific societies. The Linnean Society for the promotion of zoology and botany was founded in 1788; the Royal Astronomical Society in 1820; the Zoological Society in 1826; the Chemical Society in 1841. In Germany, under the leadership of Humboldt, the first national association for the advancement of science was established in 1828; the British Association followed in 1831. There are now special scientific societies for different sciences

and national associations for the advancement of science in all the greater countries.

The American Association for the Advancement of Science held its first meeting in 1848, being the continuation of the Association of American Geologists and Naturalists, founded in 1840. The American Chemical Society was organized in 1876; the American Society of Naturalists in 1883; the American (then the New York) Mathematical Society and the Geological Society of America in 1888. The national associations for medicine, engineering and education were organized at a comparatively early period. There are now more than fifty national societies in the United States devoted to the different branches of science.

The principal objects of these organizations have been to hold meetings for the presentation of scientific papers and in some instances to conduct journals. But they also perform to a certain extent the functions of guilds or trade unions, and this is more especially true of the societies concerned with engineering, medicine and teaching. The American Association of University Professors, organized in 1915, had such functions primarily in view, although it has been timid about the question of salaries and privileges. A union of scientific employees of the government and unions of academic teachers, affiliated with the American Federation of Labor, have recently been formed.

The American Association for the Advancement of Science has made notable progress beyond the similar associations of other nations by the support of a weekly official journal and by affiliation with the national societies devoted to the different sciences. It may be regarded as an association of these societies; they are represented by delegates on its council and have charge of the scientific programs when they meet with it. The sixteen sections of the association cover completely the pure and applied sciences, including the psychological, humanistic and political sciences. Committees of these sections are formed of representatives of the association and of the affiliated societies. The council of the association and the sectional committees are thus organized on a democratic basis to represent through the association and through the national scientific societies the scientific men of the country.

All those professionally engaged in scientific work are eligible to fellowship in the association and all those interested in the advancement of science to membership. The members number about 12,000; there are funds for research amounting to over $100,000; the annual dues are only five dollars. In England it costs fifteen dollars to be a member of the British Association and to receive the national weekly scientific journal.

The American Association has accomplished important work through its council, through its executive committee, through its sectional committees and through numerous special committees, including the committee of one hundred on public health and the committee of one hundred on scientific research. The latter committee, organized in 1914, arranged subcommittees on research in each of the sciences, on grants for scientific research, on research in educational institutions, on research under the government, on research under states and municipalities, on research in industrial establishments and in other directions. In order, however, that the association may represent and forward the interests of science and of scientific men, a more general concern for its work is essential. Scientific men are intellectually too individualistic and socially too submissive to unite with the loyalty which characterizes the trade unions. But the future belongs to the national scientific societies and to the association of scientific workers in which they are combined.

In addition to a house of commons, we still have a house of lords. The National Academy of Sciences was chartered by the Congress in the emergency of the civil war, and was made by law the adviser of the Government on scientific questions, with the stipulation that no member should receive payment for his services. It was originally limited to 50 members elected for distinction in science; the members now number about 200. The academy administers funds for research and medals amounting to over $200,000.

For some fifty years the academy enjoyed a peaceful and pleasant existence. Membership was an honor appreciated by the elect, and the social features of the meetings were agreeable to the privileged. At that time the eighteenth amendment had not been even threatened, and certainly no one ever dreamed of the application of the nineteenth amendment to the academy. The duty of listening to papers on the scientific program was not onerous, for while they were often unintelligible they were not numerous. At one meeting Benjamin Peirce, after writing, correcting and erasing equations on a blackboard for an hour, remarked that he was sorry that the only member who could understand them was in South America. The election of new members was the great event of the meeting. No other business transacted was perhaps more significant than a resolution to endorse the metric system, which was voted in the negative.

The academy has been called on by the Government to render only a few reports. Perhaps the most typical of these was to determine whether the ink with which the Declaration of Independence

was written can be prevented from fading; for it was not, of course, a question of preserving the sentiments of that document. It may also be significant that the academy holds its annual meetings in a museum and is presided over by our most eminent student of invertebrate fossils. It is said that a representative once asked in the House "What does the National Academy of Sciences do?" and the reply was: "The members write obituaries of each other when they die, and it is a pity they have so little to do."

The advice of the academy has not been sought by the government because it has developed its own departments, employing hundreds of scientific men, and the heads of the bureaus are not usually members of the academy. Advice given without responsibility and free of charge is usually worth about what it costs. When thirteen years ago the academicians made their quadrennial visit to the White House to wait upon President Taft and, following various delegations of men, women and children, passed before him, he recognized Dr. Weir Mitchell and said: "Why, Mitchell, what on earth are you doing in this crowd?" Dr. Mitchell explained with much dignity what an honorable body it was, being by law the scientific adviser of the government; but it may be doubted whether President Taft subsequently remembered the academy's existence.

President Wilson, an eighteenth century academician cast on the rough waters of the democratic politics of to-day, had appreciative sympathy for the National Academy. Shortly after his inauguration, the American Association appointed a committee to urge the selection of a scientific man for chief of the Weather Bureau, and the committee proposed to the president that he ask the advice of the academy in accordance with the provisions of the law. This he did and appointed one of the three scientific men named by the academy. He also appointed as chief of the Bureau of Fisheries the scientific man recommended by the American Society of Zoologists. Such methods are useful so long as scientific offices are in danger of being used as part of the spoils of office; but the appointment and promotion of scientific men in the government service should be through the choice of their associates, rather than on the recommendation of an outside body.

The recent revival of the National Academy has, however, not come from the modest recognition given to it by President Wilson, but is an adaptive response to modern conditions. Similar movements have occurred in the churches, in the universities and in other inherited institutions. When in the course of evolution, God let the dry land appear and saw that it was good, the creatures of the swamps suffered diverse fates. Most of them became extinct,

some survived in their shells, a few developed into the higher animals of to-day. Like the churches, the universities and the rest, the National Academy of Sciences lies at present on the knees of the Gods, and only omniscience knows its fate. It may be an eddy in the stream; it may be a stepping stone.

A proximate cause of the reanimation of the academy was the enterprise of a distinguished man of science, elected to membership at a comparatively early age, as is the fortune of astronomers—for most astronomers are born to greatness through the circumstance that the superiority of their intellect is enhanced by their costly instruments and by the inaccessibility and sublimity of the starry firmament. This able and ingenious entrepreneur in science stirred several academicians by the contagion of his enthusiasm and took the academy in hand. Lectures have been endowed for the meetings; proceedings have been established where by resolution of the academy members are instructed to bury the cream of their researches; within a single year the ex-president of the nation and the ambassador of that empire on whose commerce the sun never sets made addresses at the dinners; an earl and a prince were present. The Carnegie Corporation has undertaken to erect for the academy its marble mausoleum.

A national academy, however, is wrapped in the inertia of its great traditions and bears the Atlantean load of a crystallized earth. Most ingeniously, a National Research Council has been established as a committee of the academy. This morganatic spouse can wear the royal jewels and yet associate with ordinary scientists, engineers and the like. She can be fertile without limit in committees, as their nourishment may be entrusted to charity. For this reason she can also adopt all the children on which she can lay her hands; indeed she may entice or kidnap certain gilded youths who will add to the family wealth. She has spread her net over the oceans and has set her traps for international fish, excluding those held to be unclean.

Even the humble children of the present writer have not escaped the telescope of this mother of enterprises. While his legal offspring may stay at home, some of those of which he was only one of many guardians have been abducted. Thus all the sub-committees of the committee of one hundred on scientific research of the American Association were bodily conveyed to itself by the Research Council, and the sectional committees of the association, representing the national societies, have been duplicated by the council. The committees of the council were originally nominated in equal share by the American Association, the National Academy and the Special National Societies; the writer urged that they

should be equally responsible to those bodies. But cooperation prevailed, and when the lion and the lamb lay down together the lamb was inside the lion. The Research Council also proposed cooperation with the American Association as a whole. It offered to provide a permanent secretary for the association, to rent an office to the association in the attic of its building, and to let the association attend to the popularization of science while the council cared for research. Whether the Research Council belongs to the National Academy, or the National Academy belongs to the Research Council, or both are satellites of Pasadena, is a problem of three bodies that is difficult of solution. The American Association still belongs to its twelve thousand members, even though they have not learned to use their heritage.

The Carnegie Corporation, the Rockefeller Foundation and the National Research Council are another problem of three bodies. The Research Council depends on the endowed establishments for support, but the chairman of the Research Council became president of the Carnegie Corporation and its secretary has became a trustee of the Rockefeller Foundation. Scientific research certainly needs all the money it can get; it is in the interest of the nation that it get all the money that it needs. *Pecunia non olet.* A clergyman once told his congregation that it was well when the righteous gave to the Lord, but it was still more blessed when the money was obtained from the wicked, for then it was all gain. If we are taxed for the use of steel and petroleum, it is not amiss that a fraction of the proceeds should be returned to us for science and education. But after all the people can tax the preemptors of steel and petroleum, and it may in the long run be safer and even more profitable for men of science to be free from the charity and control of the classes of privilege and sell their services to the people for what they are worth.

One of those high in office in the National Research Council began an address:

> A general of the regular army listening to a description of the National Research Council remarked, "You are the General Staff of the Army of American men of science."

Mr. Elihu Root, trustee of many institutions and attorney for many corporations, says in a paper written for the council and widely distributed by it:

> The effective power of a great number of scientific men may be increased by organization, just as the effective power of a great number of laborers may be increased by military discipline.

It may be that the officers of the National Research Council are prepared to command the privates of science and that some

employers would like to increase the effective power of laborers by military discipline. But what do the laborers and the scientific men think about it?

Frivolity may be unbecoming in the sanctuary of the higher organization of science; but the individual organism can exhibit only those defensive reactions which are its natural response to the situation. The Rockefeller-Carnegie Research Council (the R_2C_2) is prepared to direct scientific research and has good intentions for every day on the calendar. But there you are. Dr. John C. Branner, in his admirable book of negro stories printed just before his death, tells us that long ago he visited one of the former slaves of his father's plantation and asked her: "Don't you think you were better off as a slave?" And this is what Aunt Ellen replied:

> De Lawd bless yo' soul, chile, dat's a fac'; hit's jes lak you ben a sayin'. I knows I had mo' to eat an' mo' to wear, an' a better house to live in, an' all o' dem things, an' you all was mighty good to me; an' I didn' have none o' dese here doctah's bills to pay. But Law', honey, atter all, dah's de feelin's.

Unlike the worldly-wise steward in the parable, the scientific man can dig and to beg he is not ashamed. He digs for others and then begs for a bit of the gold that he has dug. But why should he not keep for himself and for his work part of the treasure that he discovers? The applications of electricity due to research work in the laboratory add billions of dollars a year to the wealth of the world. Why can not scientific men learn how to retain even one per cent. of such wealth, which when reinvested in research would again yield high usury to science and to society? It is a long way, but the world does rise slowly in spiral course to higher levels. The prime mover is scientific research and its applications. Without the commerce and the industry created by science, there could be only a hereditary aristocracy of privilege and wealth controlling slaves. We have now reached the stage where we can at least foresee economic freedom for all. People must be fed and sheltered before they can be happy and free; they must be happy and free before they can be good and wise. Economic liberty must precede intellectual liberty. Science and its applications should be the chief concern of a democratic nation that would preserve its democracy and advance the freedom and the welfare of its people.

MARTIAN POLAR RIFTS

By Dr. G. H. HAMILTON

LOWELL OBSERVATORY

IN 1902, Dr. Lowell published an extremely interesting article on the rifts in the north polar cap of Mars (*Popular Astronomy* for March, 1902). It is on account of this article that the present paper has its being.

Realizing that the oppositions of 1916, 1918 and 1920 had occurred at about the same Martian season as that viewed by Lowell—a study was made of drawings of the planet at these times. It is interesting to note that the observations not only confirm those of Lowell but add their weight to his conclusions.

It is purposed to chronicle the observations of the three last oppositions with deductions and show in what manner they agree with the conclusions arrived at by Dr. Lowell.

In 1916, the two drawings showing the region termed *Aeria* near the center of the disk and the north polar cap—those of March 4 and 9, in the cut—depict a rift in the cap, which seemingly the continuation of the canal *Cadmus*. That of March 9 also shows another rift to the north and west of the *Arethusa Lucus*. The season on Mars corresponded at that time to our May 24. The cap was in process of melting and the rifts were seemingly due to some underlying cause such as would hasten the melting of the polar snows at those points.

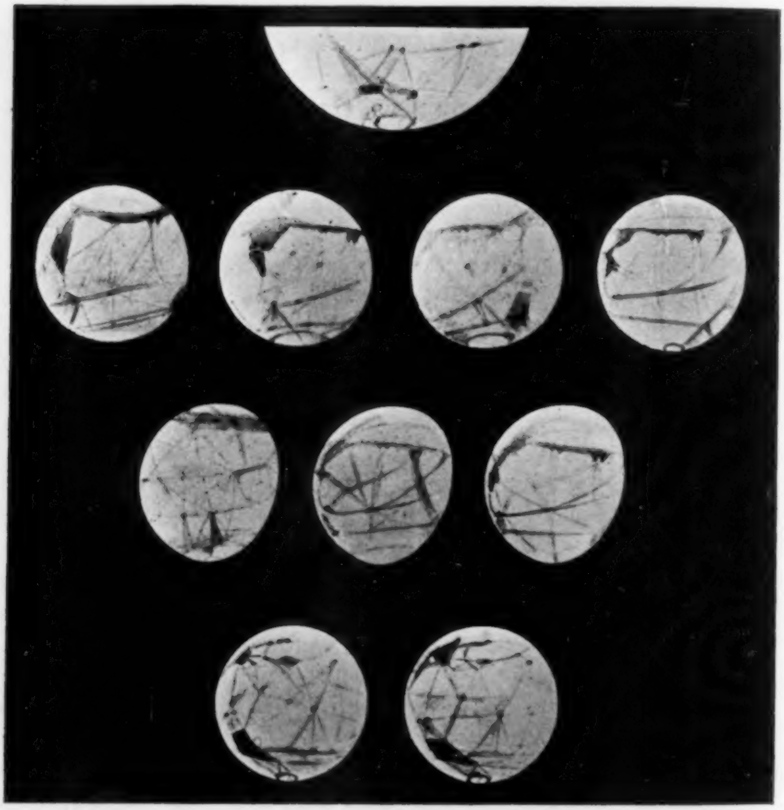
A similar rift to that in the drawing of March 9, 1916, was observed on February 15, 1918, with a period of slightly over a Martian year between the two observations. The effect of the later seasonal date can be observed in the diminished size of the polar cap. The positions of this second rift on the two dates do not correspond exactly, but this can be accounted for by the difficulty of positioning small detail or by the fact that there are many nearly parallel canals in this region, any one of which may have produced the effect observed.

In 1920, the north polar cap was at about its smallest on May 24, and the canal *Cadmus* was easily seen to extend northward to the cap along the position of the rift seen in the drawings of 1916. In the large drawing of the polar cap of May 27, 1920 (Martian date August 13) the *Cadmus* can be seen very well and there is another rift in the small remaining cap.

The action of this canal and the rift it seemingly makes in the polar cap corresponds to the observations made by Dr. Lowell and the inferences that he draws from them. He says:

> If there were strips of vegetation in the midst of the desert that underlies the polar cap, such vegetation would make its presence known by appearing as rifts in the snow-field. Such would be the case for the following reason. The life of plants has this in common with the life of animals, that their vital processes both generate heat. The fact was not recognized as true of plants until long after it was well known of animals. Indeed, the discovery that plants give out heat in growing is of comparatively recent detection.

Now the calorific action of vegetation on snow is very often observed on earth and we have seemingly had evidence of the same character upon Mars. If this be so, the two suspected materials—snow and vegetation—on the planet, vouch for each other. The



POLAR RIFTS ON MARS

May 27, 1920.
March 4, 1916. March 9, 1916. February 15, 1918. May 24, 1920.
July 8, 1920. August 2, 1920. August 3, 1920.
May 11, 1920. May 12, 1920.

snow, if it be snow, is melted as on earth by vegetation; and the vegetation, if it be vegetation, melts the snow as on earth.

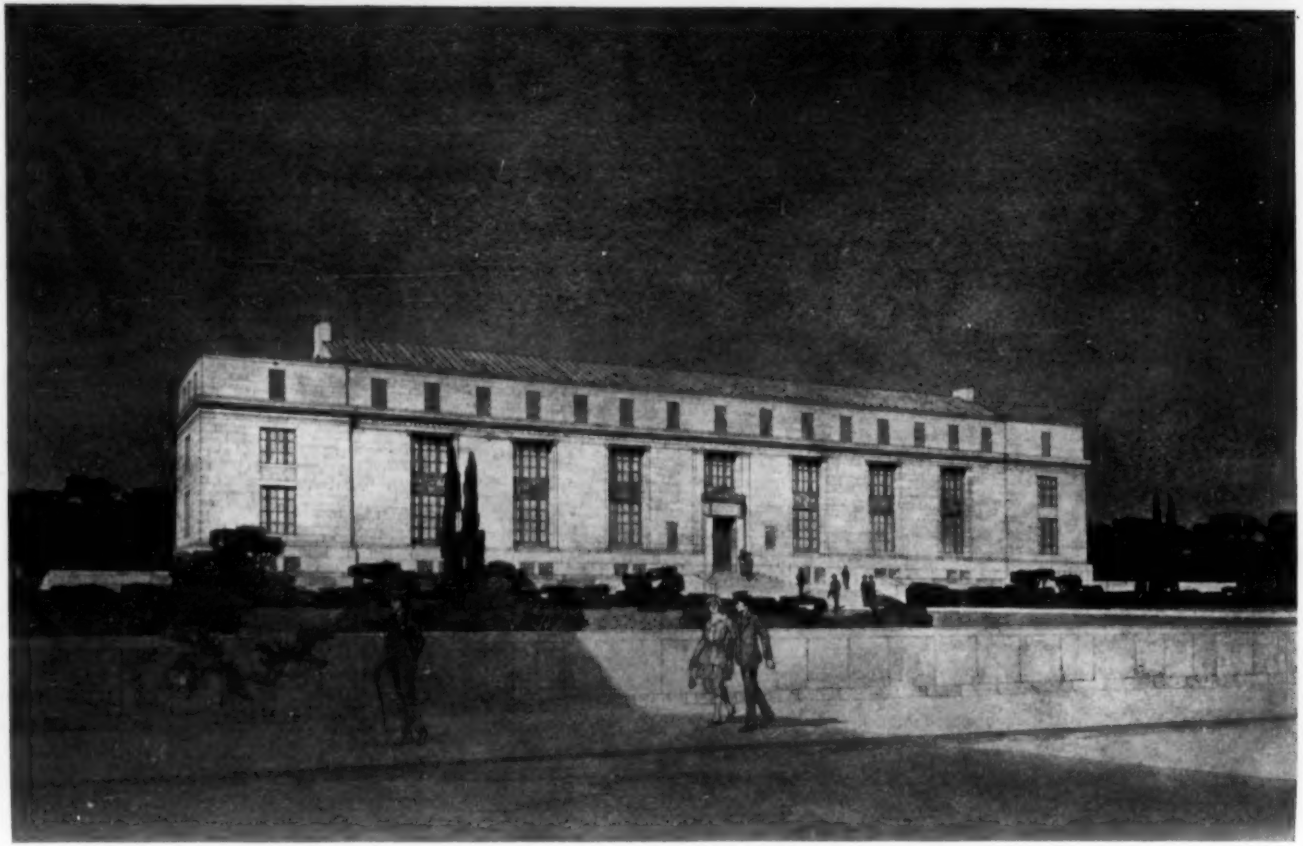
Observations of this character again were made on August 2, 1920, and the following date, September 20, Martian calendar. One of the first northern snowfalls occurred near that time, and a canal was easily seen going north from the *Arethusa Lucus*, but was obliterated completely further north by the new-fallen snow. The drawing of the next day, August 3, shows that the snow has melted over the canal—as it would over vegetation—and that there is left a rift where the day before the cap showed an even contour, but on the following is made up of two lobes, one on each side of the now triumphant and still flourishing canal.

Before this date, a snowfall occurred north of the *Proponti*, and from the rift seen in the drawing of July 8, this snow must have fallen earlier even than this and melted over the canal that leaves the *Propontis* in a northerly direction towards the cap. This is an identical example of the phenomenon seen on August 3. It is also interesting in that it shows the depth of the new-fallen snow to be much thinner, as Dr. Lowell suggests, than the old winter cap itself; which can be seen dimly, together with its dark surrounding band, through the new covering of snow.

That the tiny northern cap itself was thin is evidenced in the drawings of May 11 and 12, 1920, where a slight rift is visible cutting the cap nearly in two. This is no doubt similar to the "Open Polar Sea" that Dr. Lowell talks of in referring to the small southern cap.

Detail on Mars is so complex, and the conclusions one can draw from the secular and seasonal changes so interesting, that when by careful scrutiny of the disk a marking of great interest is observed—it would be really better to devote one's attention to that area alone and draw it—rather than attempt a drawing of the whole disk. The marking itself would be swamped in a complete drawing, without regard to the attention taken from it by an endeavor to portray the rest of the surface features of the planet.

Mars has given to this world a most interesting and instructive line of research—I might almost say vital to the future welfare of the race on Earth.



ARCHITECT'S DRAWING OF THE BUILDING TO BE ERECTED BY THE CARNEGIE CORPORATION FOR THE NATIONAL ACADEMY OF SCIENCES

THE PROGRESS OF SCIENCE[1]

BUILDING OF THE NATIONAL ACADEMY OF SCIENCES

A HOME for the National Academy in the national capital will be provided through the erection of a magnificent building costing $1,300,000 that will house the activities of the academy and the National Research Council. A description of the new building was given by Dr. C. D. Walcott, president of the academy, at the recent meeting in Washington.

Facing the Lincoln Memorial, the marble building in simple classical style will rise three stories from a broad terrace. It has a frontage of 260 feet. On the first floor there will be an auditorium seating some 600 people, a lecture hall holding 250, a reading room, library, conference rooms and exhibition halls. The basement contains a cafeteria and kitchen. The two upper floors will be devoted to offices.

The building is the gift of the Carnegie Corporation of New York, while the ground was bought at a cost of about $200,000 through the donations of about a score of benefactors. Bertram Grosvenor Goodhue of New York is the architect. He is one of the best known architects in the country and designed the St. Thomas Church, the West Point buildings, the Nebraska State Capitol and many other buildings. The contract for the construction of the building has been let to Charles T. Wills, Inc., of New York, and it is expected that the building will be ready for occupancy in the autumn of 1923. Lee Laurie, the sculptor, has been selected to do the decorations, which will symbolize and depict the progress of science and its benefits to humanity. A series of bronze bas-reliefs will show a procession of the leaders of scientific thought from the earliest Greek philosophers to modern Americans.

On passing through the entrance hall the visitor will find himself in a lofty rotunda. Here he will see in actual operation apparatus demonstrating certain fundamental scientific facts that hitherto he has had to take on hearsay. A coelostat telescope, mounted on the dome of the central rotunda, will form a large image of the sun on the white surface of a circular table in the middle of the room. Here visitors will be able to see the sun-spots, changing in number and form from day to day, and moving across the disk as the sun turns on its axis. A 60-foot pendulum, suspended from the center of the dome, will be set swinging through a long arc, repeating the celebrated experiment of Foucault. The swinging pendulum will mark an invariable direction in space, and as the earth and the building rotate beneath it, their rotation will be plainly shown by the steady change in direction of the pendulum's swing over a divided arc. Other phenomena to be demonstrated in striking form in the central rotunda are magnetic storms, earthquakes, gravitational pull of small masses, the pressure of light, the visible growth of plants, swimming infusoria in a drop of ditch water, living bacteria, and other interesting phenomena.

In the seven exhibition rooms surrounding the central rotunda the latest results of scientific and industrial research will be illustrated. One room will be set aside for the use of government bureaus, another for industrial research laboratories, others for the laboratories, observatories and research institutes of universities and other institutions. The newest discoveries and advances in the mathe-

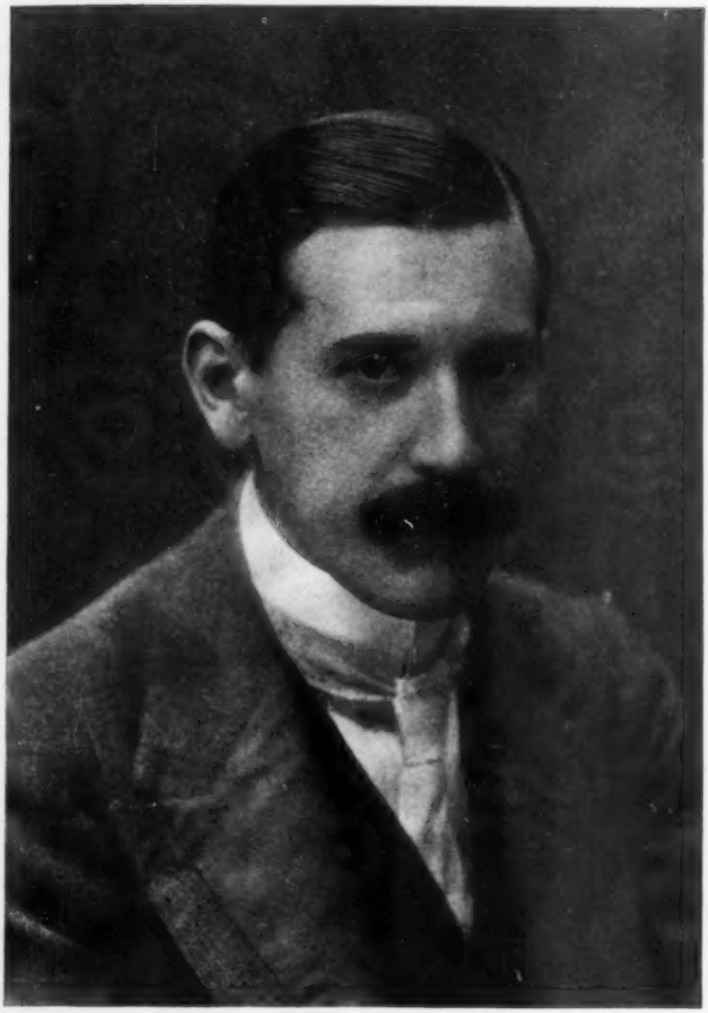
[1] Edited by Watson Davis, Science Service.

SKETCH OF ENTRANCE TO THE NEW BUILDING OF THE NATIONAL ACADEMY OF SCIENCES

matical, physical and biological sciences and their applications will be shown in this living museum, whose exhibits will be constantly changing with the progress of science. One week there may be displayed the latest forms of radio telephony; the next perhaps a set of psychological tests or a new find of fossils or a series of synthetic chemical compounds.

MEDALS OF THE NATIONAL ACADEMY OF SCIENCES

At the annual dinner of the National Academy of Sciences, April 25, the J. Lawrence Smith Medal was bestowed upon Dr. George P. Merrill, curator of geology at the United States National Museum. This is a gold medal of the value of $200, from a fund established in 1884, as a reward for "original investigation of meteoric bodies." But because investigators in this field are so rare it has not been given since 1888. Dr. Whitman Cross, in his speech presenting the medal, pointed out that Dr. Merrill had continued to carry on the work of his predecessor, J. Lawrence



OTHENIO ABEL
Professor of Paleontology in the University of Vienna.
From a photograph presented by him to Dr. Henry Fairfield Osborn.

Smith, on meteorites by the application of modern methods of analysis. The earlier analyses of meteorites were not always to be relied upon, and Dr. Merrill in his long years of research has been able to show that some of the elements previously reported as having occurred in meteorites are absent and, at the same time, he has extended the list of elements and compounds that do exist in these bodies. Among other minerals he has found a calcium phosphate similar to apatite, which has been named in his honor Merrillite. Dr. Merrill also has discovered evidences of metamorphism in meteorites, cases where a mineral structure has been broken up and the fragments later fused together like the conglomerates found in igneous rocks in the earth's crust.

Dr. Merrill in receiving the medal said that meteorites had in all ages attracted a great deal of popular interest. In the earliest times they were worshipped as divine and nowadays the newspapers give great atten-

PROFESSOR H. A. LORENTZ, OF THE UNIVERSITY OF LEIDEN, AND PROFESSOR DAYTON C. MILLER, OF THE CASE SCHOOL OF APPLIED SCIENCE

Professor Lorentz gave the principal address, entitled "Problems of Modern Physics," at the meeting of the National Academy of Sciences.

tion to any meteoric fall. Yet few scientists have made them the subject of concentrated and long-continued study. In his work, Dr. Merrill said he had tried to keep his feet upon the earth as though his shoes had leaden soles and to leave to others premature speculation as to the origin of these bodies. It is evident from their composition that they come from regions where there is no air, for they contain iron, both in a free state and in compounds that are not stable in the presence of oxygen. From their structure it is evident that some have undergone secondary igneous changes. In conclusion, Dr. Merrill quoted the verse, "All my dreams come true to other men," and said that he would leave the developments and deductions from his work to future investigators and "may all my dreams come true to other men."

The address bestowing the Daniel Giraud Elliot Medal was made by Dr. Henry Fairfield Osborn. This medal is intended to be awarded every year for contemporary contributions to zoology. Previous awards were made to F. M. Chapman, C. W. Beebe and Robert Ridgway. Dr. Osborn sketched the history of paleontology from the time when Cuvier first announced the law of correlation. The great American paleontologists, Leidy, Cope and Marsh, limited themselves mostly to description. But now again the time has come when general principles and relationships may be founded upon a more substantial basis. Among the young investigators who are taking up this work is Professor Othenio Abel, of Vienna, who has undertaken a general study of the causes of evolution. His guiding thought is that morphology depends upon physiology

and that to understand a form we must know its function. Professor Abel pursued his studies even during the war when his family was in such distress that he had to send out his children to friends for food, and in 1920 he produced an inspiring work, entitled *Methoden der Paleobiologischen Forschung.*

The medal was received by Edgar L. G. Prochnik, Austrian chargé d'affaires, who said that all Austria would rejoice over this honor done to one of her citizens. Conditions in Austria are exceedingly hard at present on account of the curtailment of Austria's resources and it is felt that the future of Austria lies in the mental power of her sons. The Austrian scientists are determined to bring their country to the rank which she occupied in science and art previous to the war. The disposal of this medal was another proof that science was not limited in its scope to creed or nationality. Professor Abel serves in the ranks of science, the peace maker. President Walcott, in handing over the medal to the representative of the Austrian Legation, said that the award would carry with it an honorarium which was to be forwarded to Professor Abel.

THE SALT LAKE CITY MEETING

THE summer session of the American Association for the Advancement of Science to be held in conjunction with the sixth annual meeting of the Pacific Division of the Association at Salt Lake City, June 22 to 24, 1922, promises to be a very successful meeting.

Salt Lake City offers many advantages as a meeting place. The center of a rich agricultural and mining section, it has large and important commercial and manufacturing interests. But it is perhaps chiefly famed for its scenic attractions drawing every year thousands of tourists by auto and railway from all parts of the country. The opportunity will be seized by many who will wish to combine a pleasure trip to one of the most interesting sections of the west with the advantages of a scientific meeting.

The hosts of the Salt Lake City meeting will be the University of Utah, the Utah Academy of Sciences, the Utah Agricultural College and the Brigham Young University. Arrangements will be made for the comfort and entertainment of visitors. The meeting will be held under the auspices of the Pacific Division of the Association. Dr. Barton Warren Evermann, the president of the Pacific Division, American Association for the Advancement of Science, will preside at the general sessions and will deliver the presidential address at the opening session on Thursday evening, June 22. He will speak on "The conservation and proper utilization of our natural resources."

An outstanding feature of the meeting will be a symposium on "The Problems of the Colorado River." The great reclamation project which has for its object the utilization of the waters of the Colorado River has already attracted wide attention. It is proposed to consider in this symposium the scientific aspects of the problems involved. The arrangement of the symposium is as follows: 1. General description of the Colorado River: Mr. E. C. La Rue, hydraulic engineer, United States Geological Survey, Pasadena, California. 2. Archeology of the Colorado River Basin: Professor H. R. Fairclough, Stanford University, California. 3. Geology of the Colorado River Basin: Dr. Frederick J. Pack, Deseret professor, department of geology, University of Utah, Salt Lake City, Utah. 4. The conservation of the waters of the Colorado River from the standpoint of the Reclamation Service: Mr. Frank E. Weymouth, chief of construction, United States Reclamation Service, Denver, Colorado. 5. The interstate and international aspects of the Colorado River problem: Dr. C. E. Grunsky,

vice-president of the Pacific Division, American Association for the Advancement of Science, San Francisco, California.

The evening address will be given by Professor James Harvey Robinson, head of the New School of Social Science, New York City, the distinguished historian of human evolution.

While none of the sections of the national association will arrange to hold sessions at this summer meeting the various fields of science will be represented in the meetings of the affiliated societies of the Pacific Division. Those scheduled to hold meetings at Salt Lake City are:

The American Physical Society.

The American Meteorological Society.

The American Phytopathological Society, Pacific Division.

The Ecological Society of America.

The Society of American Foresters.

The Cooper Ornithological Club.

The Pacific Coast Entomological Society.

The Pacific Slope Branch, American Association of Economic Entomologists.

The Plant Physiologists.

The Utah Academy of Sciences.

The Western Psychological Association.

The Western Society of Naturalists.

AN AMERICAN ANTHROPOID PRIMATE

At the recent meeting of the National Academy of Sciences in Washington, Dr. Henry Fairfield Osborn announced the discovery of a tooth giving evidence of a pre-historic and unknown species of anthropoid intermediate between the ape and the earliest man. This discovery made by Harold J. Cook, of Agate, Nebraska, in the middle Pliocene formations of that state, in addition to being important scientifically, has a timely interest because of the attacks that during the past few months have been launched at the ground work of science through the zeal of opponents of the facts of the evolution of man, and has a dramatic or comic aspect in that it comes from the home state of William Jennings Bryan.

Worn by use when its owner was alive, and worn by water in the centuries since, this tooth matches no known tooth of ape or man, modern or extinct. It is very different from the tooth of the gorilla, the gibbon or the orang. It is nearest to that of the chimpanzee but the resemblance is still remote. Nor does it resemble very closely any human molar, although it is nearer to the human than to the ape type of tooth. Consequently Dr. Osborn classifies it as a new species and genus and names it *Hesperopithecus haroldcookii*, which being translated back from the biologist's Latin means "the anthropoid from the west discovered by Harold Cook." The fossil was found in the upper phase of the Snake River beds, associated with remains of the rhinoceros, camel, Asiatic antelope and an early form of the horse, now extinct.

In 1908 the American Museum of Natural History received a similar tooth but it was so water-worn that it could not be safely identified. But the new specimen looks so much like the other that it may belong to the same species and gives hope that other parts may be found in this field.

The remarkable feature of the discovery lies in the fact that hitherto no specimens of anthropoid primates, ancient or modern, have been discovered in America, although they are common in the Old World. It is possible that this Nebraska tooth will open a new chapter in geological history which may throw light on the vexed question of the origin of man.

According to Dr. Osborn, the animal is a new genus of anthropoid, probably one which wandered over here from Asia with the large south Asiatic element which has recently

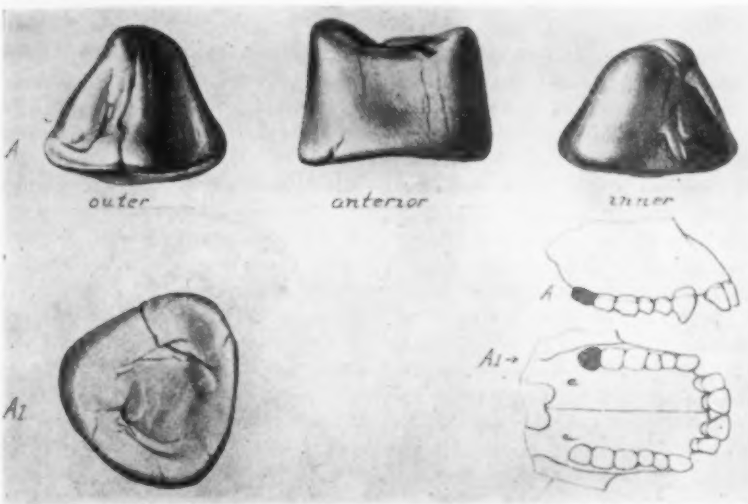


FIG. 1. MOLAR OF *HESPEROPITHECUS*

been discovered in our fauna by Drs. Merriam, Gidley and others.

Dr. Osborn and Dr. C. A. Reed, of the American Museum of Natural History, also presented evidence to the academy that man existed before the great Ice Age, which is a new and very remote date for the antiquity of man. The recent discovery of Tertiary man near Ipswich, England, known as the Foxhall man, led Professor Osborn to visit the locality and to make a very careful study of the animal life which surrounded this man. Unlike the now famous "Cave Man" of the mammoth and reindeer period, the Foxhall man was surrounded by relatively primitive mastodons, rhinoceroses, and saber-toothed tigers, also by two kinds of elephants, the straight-tusked elephant and the southern elephant. This was long before the Ice Age, when England, even in latitude 53°, was enjoying a

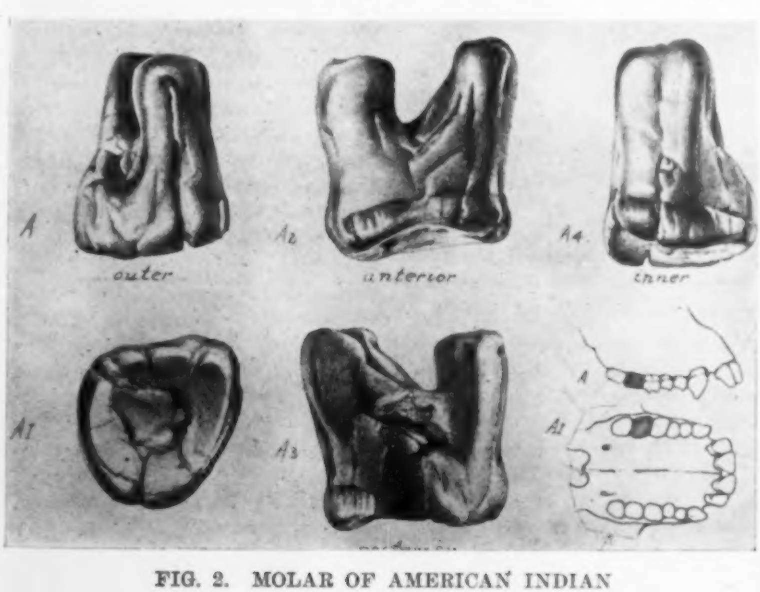


FIG. 2. MOLAR OF AMERICAN INDIAN

very mild climate. Since it is known that the Foxhall man was capable of making ten or twelve different kinds of flint implements, of providing himself with clothing, and of building a fire, he sets a new and very remote date for the antiquity of man, because he is separated from the Recent period by the whole stretch of Quaternary time, or the Ice Age. Scientific men have estimated the duration of the Ice Age from 100,000 to 700,000 years, but Professor Osborn is inclined to adopt the intermediate estimate of 520,000 years made by the German geologist, Albrecht Penck. The Foxhall man is at present known only by the flint instruments that he has left behind. Unlike *Pithecanthropus erectus*, the Heidelberg man, the Piltdown man, and the Neanderthal and art-loving Cro-Magnon races, parts of his skeleton have not yet been revealed to modern eyes.

SCIENTIFIC ITEMS

We record with regret the death of George Bruce Halsted, formerly professor of mathematics in the University of Texas; of J. T. Merz, author of *The History of European Thought in the Nineteenth Century;* of Ansel A. Tyler, professor of biology in James Millikin University; of Harris Graham, professor of pathology and practice of medicine in the American University of Beirut, Syria; of W. B. Bottomley, professor of botany in King's College, London; of Phillippe Auguste Guye, professor of physics at Geneva; and of Robert Wenger, director of the Geophysical Institute of the University of Leipzig.

At the meeting of the National Academy of Sciences, held in Washington on April 26, members were elected as follows: Edward W. Berry, professor of paleontology, the Johns Hopkins University; George K. Burgess, Bureau of Standards; Rufus Cole, director of the hospital of the Rockefeller Institute for Medical Research; Luther P. Eisenhart, professor of mathematics, Princeton University; Joseph Erlanger, professor of physiology, Washington University Medical School; Herbert Hoover, secretary of commerce; George A. Hulett, professor of physical chemistry, Princeton University; Charles A. Kofoid, professor of zoology, University of California; George P. Merrill, curator of geology, U. S. National Museum; C. E. Seashore, professor of psychology, State University of Iowa; Charles R. Stockard, professor of anatomy, Cornell Medical College; Ambrose Swasey, president of the Warner and Swasey Company; W. H. Wright, astronomer, the Lick Observatory, University of California. Dr. Albert Einstein, of the University of Berlin, was elected a foreign associate.

At the meeting of the American Philosophical Society, held in the city of Philadelphia, on April 23 and 24, the following officers were elected: *President*, William B. Scott; *vice-presidents*, Arthur A. Noyes, Hampton L. Carson, Henry Fairfield Osborn; *secretaries*, Arthur W. Goodspeed, Harry F. Keller, John A. Miller; *curators*, William P. Wilson, Henry H. Donaldson; *treasurer*, Eli Kirk Price; *councillors*, Lafayette B. Mendel, Herbert S. Jennings, William W. Campbell, Robert A. Millikan, Felix E. Schelling. Members were elected as follows: Charles Elmer Allen, Madison, Wis.; Rollins Adams Emerson, Ithaca; Worthington C. Ford, Cambridge, Mass.; Frederick E. Ives, Philadelphia; Irving Langmuir, Schenectady; Roland S. Morris, Philadelphia; George William Norris, Philadelphia; Charles Lee Reese, Wilmington; Harlow Shapley, Cambridge, Mass.; Henry Skinner, Philadelphia; James Perrin Smith, Palo Alto; Charles Cutler Torrey, New Haven; Robert DeCourcy Ward, Cambridge; Henry Stephens Washington, Washington; David Locke Webster, Stanford University.

INDEX

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